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and
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HAZARDOUS WASTE REDUCTION AUDIT WORKSHOP

Presented by

New Jersey Department of Environmental Protection

Division of Hazardous Waste Management

Hazardous Waste Advisement Program

401 East State Street

Trenton, New Jersey

and

United States Environmental Protection Agency

Hazardous Waste Engineering Research Laboratory

Cincinnati, Ohio

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Technical Coordinator
NAPIM

Lever

Lever Research and Development Center
45 River Road
Edgewater, New Jersey 07020
(201) 943-7100

Lever Edge Tlx 640333

THE R&D SECTOR: OPTIMIZING WASTE MINIMIZATION PRACTICES

Abstract:
Waste minimization in the research and development sector must be implemented in accordance with the premise upon which R & D is built; innovation and creativity. In a manufacturing situation, processes may be streamlined which maximize waste reduction. R & D however, may only optimize, or make the most effective use of waste minimization through creative implementation of a unique and facility-specific program. A variety of practices and procedures currently used in the R&D industry shall be reviewed for practical application purposes.

WASTE REDUCTION IN THE R&D INDUSTRY

The R&D industry is a significant contributor to the economic base in New Jersey and is growing both in magnitude and in importance. Along with this growth has come the realization that hazardous waste management for R&D organizations presents unique challenges and problems not encountered by manufacturing facilities, primarily due to the variability and diversity of R&D activities and types of waste generated. This paper presents approaches which are proving to be successful for R&D facilities and describes a technique whereby environmental audits of new experimental units can be conducted during the project's design phase, prior to construction and operation. In addition, common difficulties encountered with the tracking and reporting of R&D industry waste reduction efforts are discussed. A future challenge which could perhaps provide the most significant long term reduction in industrial hazardous waste generation is suggested.

Steven C. Rice, P.E.
Corporate Ecology
BASF Corporation
November, 1987

THE USEPA WASTE MINIMIZATION RESEARCH PROGRAM

Harry Freeman
Hazardous Waste Engineering Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

Abstract

In an October 1986 Report to Congress on the Minimization of Hazardous Waste, the USEPA identified several technical barriers to the adoption of waste minimization in the country. As part of its program to encourage waste minimization, the Agency has initiated several research programs to provide information to reduce the technical barriers. The program which includes demonstration at large and small generator sites, waste minimization audits, cooperative projects with other state and federal agencies, and long term research is the subject of this presentation. The author outlines present and proposed programs and discusses the overall direction of the Agency's research program to support and encourage waste minimization.

ABSTRACT PRESENTATION

Waste Minimization Audit Case Studies at Various Industrial Facilities

The EPA Office of Research and Development, Hazardous Waste Engineering Research Laboratory (EPA/ORD/HWERL), Cincinnati, Ohio, has supported an ongoing two year effort to promote the use of waste minimization audits (WMAs) at industrial facilities, in order to demonstrate the use of a WMA protocol developed for this purpose. The incentive for this program derives from the EPA Report to Congress which emphasized the need for Hazardous Waste Minimization and underscored EPA's role in this effort.

WMA effort has included the performance of six audits at four facilities in 1986, covering four generic hazardous wastes (corrosives, heavy metals, solvents, and cyanides). The 1987 effort includes four audits at four facilities and covers specific K and F wastes on the EPA/ORD/HWERL highest priority list. The current studies are directed towards minimization of listed wastes K071, K106, K048-K052, F002, F004, and F006.

This presentation will present a brief review of the WMA protocol and summaries of the audits developed to date.

HAZARDOUS WASTE MINIMIZATION AUDITS FOR THE ORGANIC CHEMICAL INDUSTRY

Sam N. Popowcer, P.E.
Senior Engineer
BCM Engineers
Trenton, NJ
and
Plymouth Meeting, PA

I. Overview of Hazardous Wastes from the Organic Chemical Industry

  A. Production of Organic Chemicals

  B. Hazardous Waste Production

    1. Air Emissions
    2. Wastewater
    3. Solid Wastes

II. Hazardous Waste Audits

  A. Types of Audits

  B. Questions Addressed (why, how, and what to do)

  C. Considerations in Developing Audits for Organic Chemical Facilities

III. Options for Hazardous Waste Minimization

  A. Source Control

    1. Raw Material
    2. Technology
    3. Elimination of product line

  B. Process Changes

  C. Operational Changes

  D. Good Housekeeping Practices

  E. Equipment Changes

  F. Product Reformulation

  G. Chemical Substitution

IV. Case Studies

ZERO DISCHARGE, ZERO POLLUTION, AND SOURCE REDUCTION

Robert H. Elliott, Jr.
President of ZERPOL CORPORATION
Hatfield, Pa. 19440

Abstract

Zero discharge is cementing over the drain and recycling all the water to accomplish end-of-pipe pollution abatement. Zero pollution is collecting the three separations from the system - namely metals, organics, and salts - and making sure that these wastes are destroyed or made non-hazardous permanently. Source reduction or in-line recovery of metals should be carried out only if it is economically feasible. In most cases the cost of the recovered metal must be less than the market price.

Waste Classification and Tracking -
A Tool for Waste Minimization

Presented by
Richard A. Dennis
Manager, Environmental Affairs
Chemical Group
American Cyanamid Company
Wayne, New Jersey

Abstract

American Cyanamid Company is aggressively pursuing waste minimization with the aid of a computerized waste classification and tracking system. The first step is a complete plant waste audit. After all wastes from each manufacturing process have been identified and characterized, they are systematically classified and entered into a computerized data base. Quantative waste generation and disposal data are periodically entered for each waste. The system generates a wide variety of reports which permit us to target specific wastes and processes for minimization efforts and to monitor the effectiveness of completed minimization projects.

ABSTRACT

TECHNIQUES AND APPLICATION OF ULTRA FILTRATION AND REVERSE OSMOSIS IN WASTE MINIMIZATION

William F. Weber
Du Pont Separation Systems
E. I. du Pont De Nemours & Company, Inc.

Advances over the last 20 years have led to the economical use of cross flow membrane technology in treatment of various liquid processes/effluent streams.

Of special interest due to recent environmental regulations has been the emphasis placed on the use of this innovative separation technology towards waste reduction.

The presentation will outline the theory behind membrane separations and then will discuss our approach to the practical application of this technology to real world industrial waste reduction applications.

An excellent article covering the fundamentals of membrane separation processes was presented in the June 11, 1984 issue of Chemical Engineering and is attached as a reference.

Du Pont Separation Systems, a division of the Du Pont Company, has accessed the corporation's technical capabilities to develop and deliver hybrid membrane systems which are based on ultra filtration or reverse osmosis. We have been approached on a wide variety of applications, but most of our experience is in the following areas:

1) Metal Finishing Industry

- Plating Rinse Water Recovery
    - Cu^+ CN^- - Copper cyanide
    - Zn^{2+} CU^+ CN^- - Brass cyanide
    - Zn^{2+} CN^- - Zinc cyanide
    - Ni^{2+} - Watts nickel
    - Cr^{6+} - Chrome
- Alkaline Degreaser Recovery
- Plating Waste Treatment
    - Pretreatment of mixed and/or chelated plating streams to insolubilize heavy metals for removal by membrane filtration.

2) Textile Industry

- Concentration or Purification of dilute organic waste streams
    - Finishing Oils
    - Dyes
    - Sizing Agents

3) Chemical Processing Industry

- Concentration or Purification of dilute organic waste streams
    - Dispersants
    - Emulsified oils
- Polish scrubber effluent streams
- Product recovery of intermediates
- Product enhancement and purification

Some specifics on our involvement in several of these applications is given in the attached reprint of a related presentation at the Membrane Planning conference in November, 1986.

Introduction to Environmental Auditing

Presented by
Lawrence B. Cahill
Vice President
Hart Environmental Management
Cherry Hill, New Jersey

INTRODUCTION TO ENVIRONMENTAL AUDITING*

Lawrence B. Cahill
Vice President
Roy F. Weston, Inc.

1. Environmental regulations are increasing

Environmental (health and safety) audits have become a common technique used be regulated entities to assure management that its facilities are operating consistent with all applicable rules and regulations. Audits have become all the more important as the volume of Federal and state regulations has virtually exploded in the past few years. As demonstrated by Exhibit 1 on the following page, Federal environmental regulations have grown by almost 50% since 1981. This growth is complicated by a variety of state initiatives in the areas of air toxics and community right-to-know. Companies in Wisconsin, California, and New Jersey, in particular, find themselves in states that rank 1,2, and 3 respectively, out of 50 with regard to regulatory stringency.

2. Enforcement is also increasing at the same time

2.1 The U.S. Environmental Protection Agency (USEPA) has reemphasized its enforcement role and has moved toward a policy of taking enforcement action against corporate officials as well as their companies. A record 342 enforcement cases were referred by USEPA to the Department of Justice in the government's Fiscal Year 1986 (ending September 30, 1986). This represented a 25% increase over the previous year. This Federal and comparable state activity resulted in some interesting actions:

- In October 1986 the president of a Wisconsin printing company was sentenced to 10 days in jail, a $10,000 fine, and was ordered to place a newspaper ad warning the community not to commit environmental crimes.

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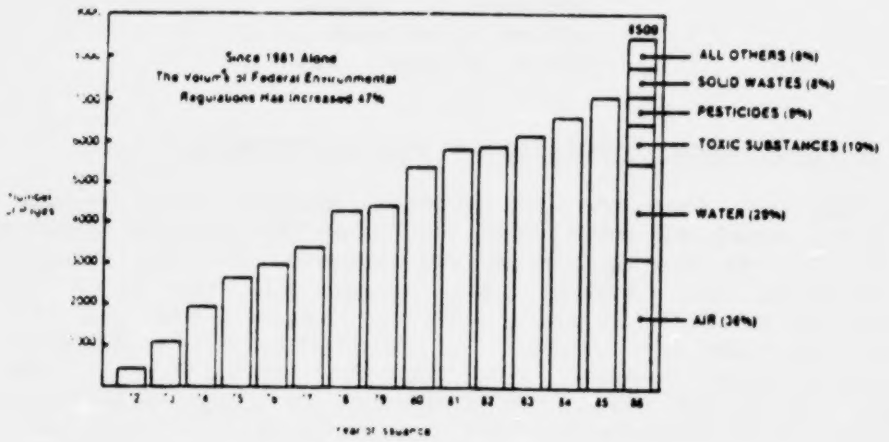
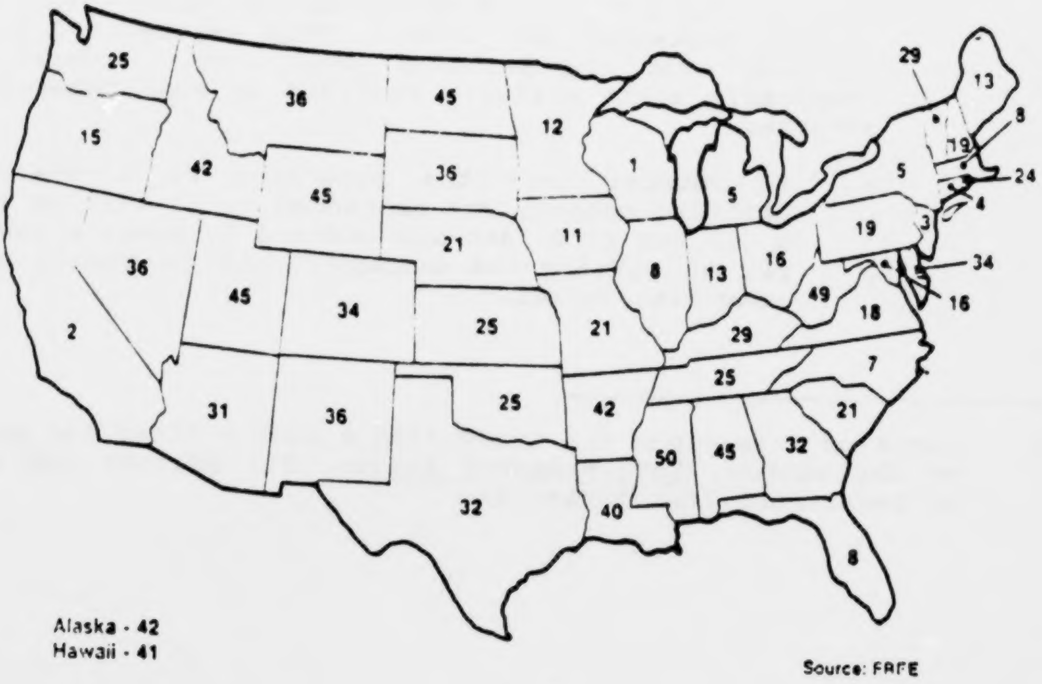
* Parts of this paper are taken from a book written and edited by the author, Environmental Audits, 5th Edition published by Government Institutes, Inc.

EXHIBIT 1

Growth of Federal Environmental Regulations (Title 40 of the Code of Federal Regulations)



Ranking State Environmental Programs



Alaska - 42
Hawaii - 41

Source: FRFE

- On September 12, 1986 U.S. Federal Court imposed a prison sentence of one year against the manager of a food processing plant owned by a Fortune 100 company for violations of the Clean Water Act. The company also paid $700,000 in fines, trust funds, and surety bonds.

- The owner and former officers of a bankrupt company were sued by the State of New York on December 12, 1986 for $5 million in damages for alleged groundwater contamination at the plant site.

- As of November 1986, the owner of a graphics company in New Jersey faced charges that could bring him more than 14 years in prison for allegedly dumping only 30 gallons of nitric acid on his property.

- In December 1986, two Pennsylvania chemical company's officers were sentenced to two years in jail (all but 30 days and six months suspended), a $10,000 fine, two years probation, and 200 hours of community service for RCRA violations.

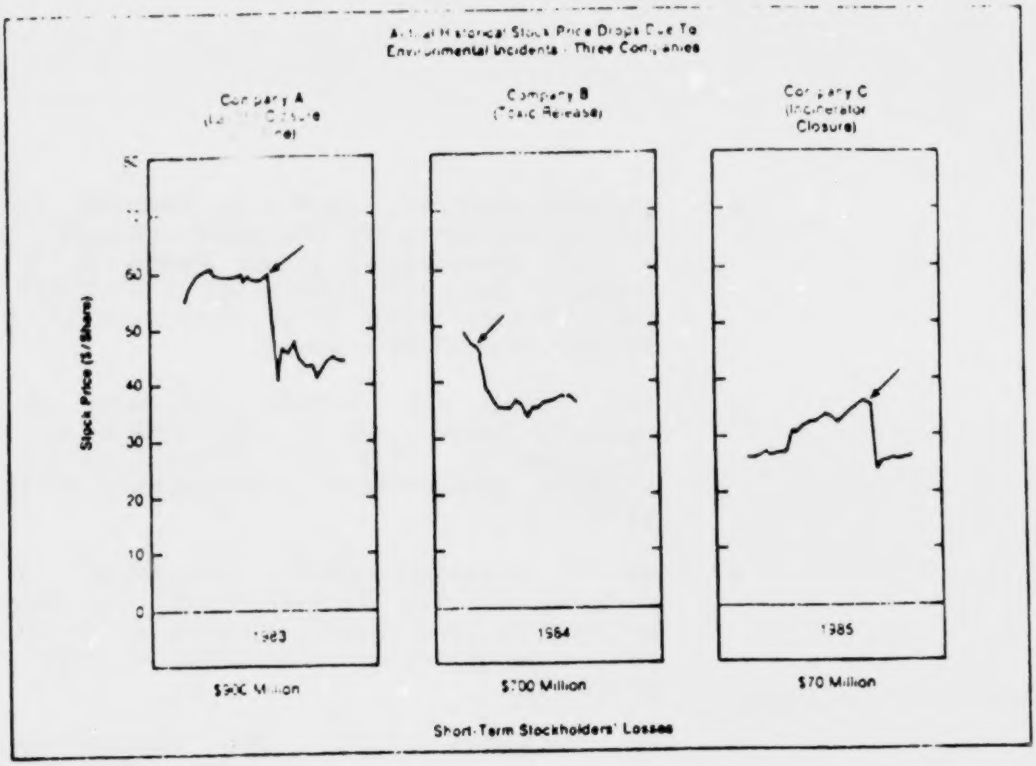
3. The meaning of liability

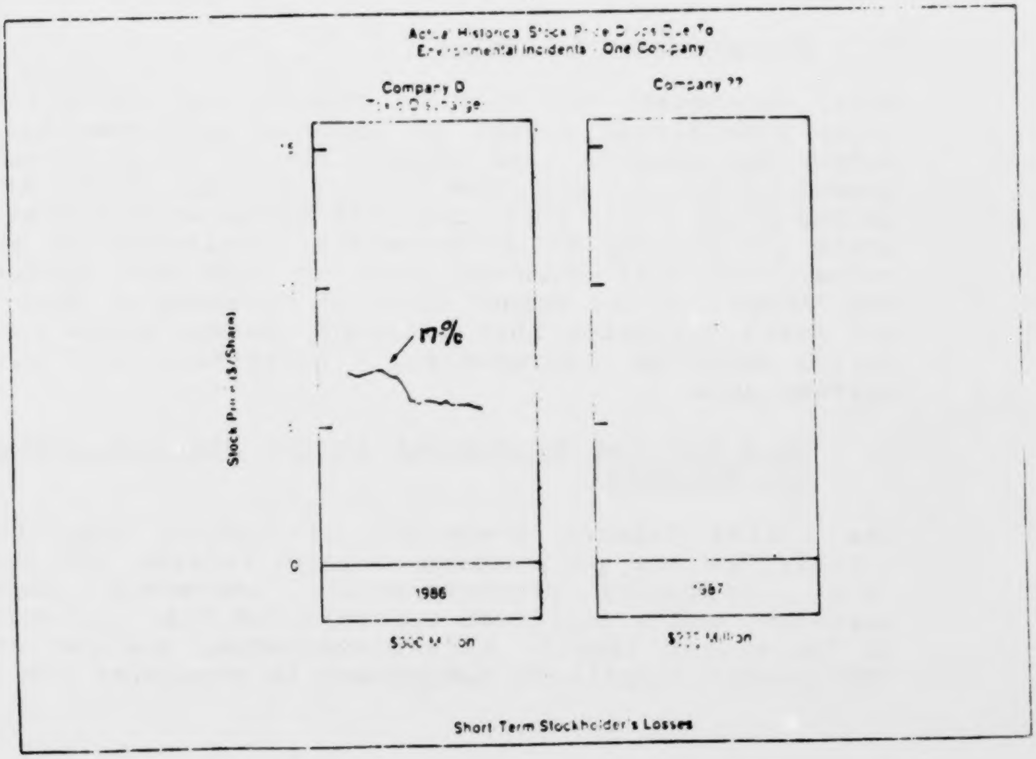
Thus, management has much to protect and can ill-afford facing major liabilities caused by improper environmental, health and safety management. And these liabilities are real as is evidenced by Exhibit 2 on the following page. Three major companies in the years 1983, 1984, and 1985 suffered severe shocks to their stock prices due to environmental incidents in each of these years. And this occurred again in 1986 when Sandoz experienced the "Bhopal on the Rhine" spill in November of that year. In the two weeks following that incident, Sandoz stock fell 17% on the Zurich exchange, representing a short-term $300 million loss to shareholders.

4. This has led to changes in the way U.S. industry conducts its business.

The rising Federal oversight is further complicated by some totally new and potentially onerous Federal and State initiates (e.g., Community right-to-know), increased competition from overseas, and a continued emphasis for U.S. industry managers to do "more with less." As a consequence, one can only wonder if "fail-safe" compliance management is possible; yet the increased

EXHIBIT 2


Actual Historical Stock Price Drops Due To
Environmental Incidents - Three Companies
Company A
Closure
Company B
(Toxic Release)
Company C
(Incinerator
Closure)
Stock Price ($/Share)
50
60
50
40
30
20
10
0
1983
1984
1985
$900 Million
$700 Million
$70 Million
Short-Term Stockholders' Losses


Actual Historical Stock Price Drops Due To
Environmental Incidents - One Company
Company D
Toxic Discharge
Company ??
Stock Price ($/Share)
15
0
17%
1986
1987
$300 Million
$??? Million
Short Term Stockholder's Losses

consequences of non-compliance suggest that it is virtually mandatory. Hence, corporate managers must exercise "due diligence" in meeting present and anticipated environmental requirements to protect both their companies and themselves.

5. Emerging Corporate Strategies

5.1 Companies of all sizes are reorganizing, establishing or consolidating EH&S programs and designating corporate officers.

5.2 Policy and Procedure documents are surfacing, addressing:

- Incident response reporting
- Regulatory agency inspections
- Environmental recordkeeping
- Audit/assessment programs

5.3 Access to special environmental legal counsel and experts is being sought.

5.4 Audit programs, in particular, are being initiated in all types of industries, including: basic manufacturing health care, banks, and real estate.

6. Audit Program Development

Like most anything in life, audit programs can be characterized by both advantages and disadvantages, the latter coming principally in the form of costs to the organization. On the positive side, audits result in a number of significant benefits, including:

- Better compliance
- Fewer surprises
- Fewer fines and suites
- Better public image with the community and regulators
- Potential cost savings
- Increased information transfer

Yet, as will be discussed in more detail in other chapters in this book, these benefits can be offset by some real and potential costs:

- The commitment of resources to run the program
- Temporary disruption of plant operations
- Increased ammunition for regulators

- Increased liability where one is unable to respond to audit recommendations involving significant capital expenditures.

Notwithstanding these drawbacks, most firms when faced with question, "Audit program, yes or no?, have opted to undertake a program. The general theory is that in this day of increased litigation and possible criminal suits, it is better to know your liabilities than to remain oblivious to them. As was stated by former U.S. EPA General Counsel: "Management ignorance is no defense!"

7. Other Initiatives

Audit program findings and concerns over liability have changed the way U.S. industry is doing business. Some of the more interesting environmental trends include:

8. Clean Air

8.1 Stringent VOC-control standards have resulted in more sophisticated end-of-pipe treatment (increased incineration) and rethinking of product lines (e.g., solvent-based vs. water-based coatings).

8.2 Industry is more likely to locate in attainment areas.

8.3 Companies are bartering of emissions credits as part of emissions banking programs.

9. Clean Water Act

9.1 More inside/rooved storage of hazardous materials is being built to minimize contaminated stormwater runoff.

9.2 Elaborate locked/diking systems for outside storage are being installed.

9.3 Because of tighter municipal standards, there is an increased need for pretreatment systems putting companies in the wastewater treatment business.

9.4 Companies are abandoning old buildings or sealing floor drains to minimize discharges to sanitary/storm sewers.

9.5 SPCC plans are sometimes needed for even small facilities.

10. The Resource Conservation and Recovery Act

10.1 "Joint and several" and "strict" liability has created a dilemma; go off-site, lose control but no permitting hassles; stay on-site, gain control but pick-up permitting hassles.

10.2 At a minimum, for off-site disposal, generators audit facilities and follow trucks; think of the business as extending to disposal; everybody is a "deep pocket".

10.3 There is a great incentive and requirement (on waste manifests) for material substitution and waste minimization; are chlorinated solvents worth it? Land disposal restrictions are having a major impact.

10.4 There is a great increase in costs of disposal making bottom-line; the increase is from technology-forcing regulations and off-site capacity problems.

10.5 Underground storage tanks are now being removed but will they be replaced with above ground tanks that will present fire and explosion problems?

10.6 Secondary containment of hazardous waste lines and tanks are requiring ripping-up of existing process systems.

10.7 Used oil give-away programs are no longer possible.

11. Superfund

11.1 Even the smallest companies are becoming PRP's requiring increased legal assistance.

11.2 Spill reporting protocols need to be in place.

11.3 OSHA and Title III are requiring increased disclosure to local communities on raw materials, products, and wastes; materials balances may even be required. This is a real sleeper; it could cause disclosure of sensitive information and a general intrusion into how industry conducts its affairs.

12. Property Transfers

12.1 States such as New Jersey and Connecticut require certification on "clean" before any property is transferred (including changes in leases).

12.2 Banks are becoming more concerned so lenders may require certification as well before any property transfers.

12.3 Current trend is "buyer beware" except that SARA provides protection if buyer conducted "due diligence" assessment.

13. Toxic Torts and Product Safety

13.1 Examples abound:

- Johns-Manville (Asbestos)
- The Chemical Industry (Agent Orange)
- Hooker (Love Canal)

13.2 Some attorney's believe this to be the wave of the future.

13.3 Compile your MSDS's for raw materials, products; know your TSCA rules; keep informed on new health data.

14. The Lessons to be Learned

14.1 Know your materials and know your exposures; think of your facility as extending out to your suppliers, customers, neighbors, and waste handlers.

14.2 Understand the regulations as best you can; use your trade associations.

14.3 Look hard at material substitution, waste minimization and treatment vs. disposal; do an audit of your facility (ies).

14.4 And lastly, understand your personal liabilities.

- Does company have clear policies on EH&S (e.g., reporting releases)?

- Does someone have responsibility and authority for carrying out policies?

- Is communication open?

- Are there procedures at plant level (e.g., disposal contractors)?

- Will the company defend you if you're charged with a criminal offense or if an individual fine is levied (e.g., Ciba-Geigy at Toms River or Nabisco in Washington)?

14.5 It's not as frightening as it seems however. The key phrase is "due diligence". If that can be demonstrated then, most of the time, equitable solutions to problems can be negotiated.

Development and Application of a Waste Minimization Audit Procedure at Industrial and DOD Installations

Presented by
Dr. Marvin Drabkin
Versar Inc.
Springfield, Virginia

Coauthored by:
Harry M. Freeman
Hazardous Waste Engineering Research Laboratory
U. S. Environmental Protection Agency
Cincinnati, Ohio

and

Carl Fromm
Jacobs Engineering Group, Inc.
Pasadena, California

DEVELOPMENT AND APPLICATION OF A WASTE MINIMIZATION AUDIT PROCEDURE AT INDUSTRIAL AND DOD INSTALLATIONS

Mr. Harry M. Freeman
Hazardous Waste Engineering Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, Ohio

Dr. Marvin Drabkin
Versar Inc.
Springfield, Virginia

Mr. Carl Fromm
Jacobs Engineering Group, Inc.
Pasadena, California

Abstract

The USEPA is encouraging hazardous waste generators to develop programs to reduce the generation of hazardous waste. To encourage such programs the Agency's Hazardous Waste Engineering Research Laboratory is supporting the development and evaluation of a model hazardous waste minimization audit (WMA) procedure. The procedure has been tested in a number of industrial and DOD facilities during 1986 and 1987. In this paper the authors describe the WMA procedure and report on the results of four case studies selected from a total of ten such studies carried out to date to test the auditing procedure.

For presentation at the Hazardous Waste Reduction Audit Workshop, co-sponsored by the New Jersey Department of Environmental Protection and the USEPA, Whippany, New Jersey, November 17, 1987.

INTRODUCTION

Structured programs designed to reduce the cost and improve energy efficiency, environmental effects, safety or other aspects of an industrial undertaking are not a new concept. During World War II, the General Electric Corporation developed standardized procurement procedures for reducing product cost without sacrificing functionality. Later, similar procedures were developed and applied to reduce the costs of design and construction projects. This activity, known as value management, value engineering, or value analysis, is currently well established as a government requirement. In fact, it was mandated by the U.S.EPA for construction projects involving wastewater treatment plants; a subsequent study of 156 treatment plants showed that cost reduction programs saved $95 million, for a 12 to 1 return on investment (1).

Waste Minimization (WM) is a value management activity with a primary objective to reduce the quantity and/or toxicity of production wastes in a manner consistent with the goals of protecting human health and environment. Unlike environmental audit programs, a WM program does not seek to determine or improve the regulatory compliance status of a facility. Rather, it is primarily oriented toward producing a set of effective measures to reduce waste generation.

Table 1 presents a breakdown of WM program elements. In the context of an overall WM program, the waste auditing process (composed of pre-audit, audit and post-audit, phases) follows the program initiation/planning phase. During this initiation/planning phase, the commitment of top management to reduce waste generation must be first established. This is often done with a formal directive signed by the chief executive officer of the firm or an administrator of a government organization. The organizational commitment to start a WM program is often associated with a goal-setting process. In this regard, DuPont has adopted an annual 5 percent waste reduction goal (2).

A WM program can be organized in a typical pyramid structure, with command and monitoring functions centered at the organization's top management level and implementation responsibility totally delegated to individual plants. An independent expert task force (reporting to top management) can be formed to assist individual plants with setting up and executing their own WM programs.

At the individual plant level, the WM program can follow the scheme successfully used at Union Carbide for energy conservation efforts. At Union Carbide plants, a plant program coordinator is appointed and supported by a committee. The coordinator then selects and oversees individuals in each department who are responsible for devising and/or carrying out WM activities in their department (3).

The program planning phase should include selection of audit team(s) to carry out the next program phase. The audit team leader should have a strong technical background, demonstrated problem solving ability, and, preferably, experience associated with the relevant process(es). Additionally, the leader should possess strong management and communication skills and should be free of previous association with the plant to avoid bias. Such individuals can be independent consultants or qualified personnel from other plants.

The organization should be prepared to provide the audit team with access to a wide range of people inside and outside of the firm. This approach was affirmed as a result of a study conducted during a recent internal workshop of a major U.S. corporation (4). The teams employed in carrying out the four audits summarized in this paper were composed entirely of employees of outside consulting/engineering firms.

The waste auditing process described in detail in the next part of the paper, provides the key input to the implementation phase of the program, i.e., recommendations on which WM measures are to be based. Following completion of the implementation phase, ongoing production monitoring is conducted in order to ascertain the waste reduction effectiveness of the changes made.

THE WASTE MINIMIZATION AUDITING PROCEDURE

As shown in Table 1, waste minimization audits are a central part of a WM program. The auditing process is subdivided into pre-audit, audit, and post-audit phases. The recommended sequence of steps is shown in Table 2. The following sections detail each of the eight sequential steps of the recommended waste minimization audit (WMA) procedure shown in Table 2.

Preparation for the Audit

The objective of this activity is to gain background information about the facility to be audited. Preparation should include examination of literature references related to the activities performed at the facility such as EPA background documents on the industries involved, plant permit applications and other relevant documents pertaining to waste discharge at the industrial facilities of interest. The result of proper preparation should be a well-defined needs list (as shown in Table 3), inspection agenda, or a checklist detailing what is to be accomplished, what questions or issues need to be resolved, and what information needs to be gathered.

Host Site Pre-Audit Site Visit

The purpose of this meeting is for the audit team to become familiar with plant operations and with plant personnel. Initial contacts with plant personnel should include solicitation of their views on the focus and function of the audit. This will help to identify waste streams of concern to the facility. The information needs defined in the previous step would be discussed here and hopefully filled. A guided tour of the facility should be taken.

At this initial visit, the ground work for a successful working relationship with facility personnel must be laid. The importance of a cooperative attitude and active involvement by host facility personnel to the success of the audit process must be stressed. The initial point of contact at the facility (Plant Manager, Environmental Coordinator, etc.) must be enlisted a a "Product Champion" for the program before the audit commences. He/she must be encouraged to relay the message of cooperation and involvement to others at the facility.

Waste Stream Selection

The criteria used for selecting a waste stream should include at a minimum:

- Composition
- Quantity
- Degree of hazard (toxicity, flammability, corrosivity)
- Method and cost of disposal
- Potential for minimization and recycle
- Compliance status

Waste stream selection terminates the pre-audit stage of the procedure. At this point, it is recommended that a written description of the facility, process, or operation and of waste streams be developed. The description should encompass:

- Facility location and size.

- Description of operations or processes of concern, including diagrams necessary to detail the pertinent aspects of waste generation.

- Waste stream(s) description centering on sources and current methods of management; this information should be supplemented with summaries of generation rates, compositions, disposal costs and raw material costs. The rationale for waste selection should also be provided.

Host Site Waste Minimization Audit Visit

With the needed understanding of the proce[illegible]nd focus in place, the audit inspection can now be conducted. Typica[illegible] the inspection will focus on the select aspects of the operation identified through the pre-audit activities. The governing objective is to evolve a fuller understanding of principal and secondary causes of waste generation and to cover the items missed in the pre-audit stage.

The audit inspection is the ultimate step in the information gathering process. The following guidelines are suggested:

1. Have an agenda ready -- this should cover all points that still require clarification following the pre-audit work.
2. Plan on inspections of the various process operations of interest at different times during the production shift for continuous processes such as acid pickling, in order to observe possible fluctuations in normally steady state operations. Expect to monitor operations over a period of one to two days.
3. Obtain permission to interview the operators, eight-hour shift supervisors and foremen directly. Listen attentively, and do not hesitate to question more than one person if the answer is not forthcoming. Try to assess the operators' and their supervisors' awareness of waste generation aspects of the operation. Note their familiarity (or the lack thereof) with the impacts their operation may have on other operations.
4. Obtain permission to photograph the facility. Photographs are especially valuable in the absence of plan layout drawings. Many details can be captured in photographs that otherwise could well be forgotten or inaccurately recalled at a later date.
5. Observe the "housekeeping" aspect of the operation. Check for signs of spills or leaks. Ask to visit the maintenance shop and inquire about their problems in maintaining the equipment leak-free. Assess the overall cleanliness and order of the site.
6. Assess the level of coordination of environmental activities between various departments.

It is of benefit during the planning and conduct of the audit inspection itself to mentally "walk the line" from what is understood to be the source of waste generation to the point of waste exit and disposal. The audit inspection must result in a clear understanding of waste generation causes, treatment and disposal.

Generation of WM Options

The next step is to generate a comprehensive set of WM options. Such activity may take a form of a "brainstorming" session involving audit team members or may involve separate efforts by individual members. A combination of these approaches was found to be of value during the audits reported on in this study. In this stage of the audit process, it is important to generate as large a number of options as possible. The WM measures currently in place in the audited facility should also be listed. This knowledge often leads to formulation of additional options and provides a valuable insight for the subsequent option evaluation step.

Options generation should generally follow the hierarchy in which most of the effort would focus on source reduction, with the alternative being recycling/reuse. If no options are available in these two areas, then treatment options would be considered. Such a hierarchy of effort stems from the environmental desirability of source reduction over recycling and of recycling over treatment. Current EPA-proposed definitions of waste minimization and of key waste minimization terms are given in Figure 1. A generalized guide map to various source reduction elements is given in Figure 2. A generalized approach to the recycle/reuse WM approach is shown in Figure 3. For discussion of the terms and examples illustrating each element, the reader is referred to the EPA support document for the 1986 Report to Congress on Waste Minimization (5).

To generate options, it is often necessary to examine the technical literature. Options can also be formulated through discussion with manufacturers of equipment or suppliers of process input materials.

The result of the WM options generation step should be a list on which each option is identified, together with a brief description of the rationale for listing.

Preliminary Evaluation and Rating of Options

Each of the options postulated in the preceding step must undergo a preliminary engineering evaluation and rating. The objective of this evaluation is to weed out the measures that do not merit additional consideration and to rank the remaining measures relative to their overall desirability.

The evaluation should include, at a minimum, consideration of the following aspects:

- Waste reduction effectiveness (i.e., reduction of waste quantity and/or toxicity)
- Extent of current use in the facility
- Industrial precedent

- Technical soundness
- Cost (preliminary capital and operating cost evaluation)
- Effect on product quality
- Effect on plant operations
- Implementation period
- Resources availability and requirement

The preliminary evaluation of selected options would consist of the following steps carried out by the audit team:

(a) Development of a written rationale for each proposed option including a clear description of the operating principle, estimates of waste minimization measured in pounds of waste and in pounds of waste per unit production, estimates of potential resource recovery measured in pounds of waste component recyclable to the process or salable as a recovered material, perceived advantages and disadvantages, simplified schematics of the proposed material flow, material balance calculations, "order of magnitude" cost estimates, references relating to prior applications and other relevant documentation pertaining to the idea.

(b) Qualitative rating of each option in three categories: waste reduction effectiveness, extent of current use, and future application potential. The ratings are to be done on a scale of 0 to 10 by a proponent -- then reviewed by the audit team leader.

It is expected that some options may receive ratings low enough to warrant their withdrawal. The team leader may call a review meeting to submit the ratings to a collective discussion or vote.

The product of this effort should be a table in which preliminary ratings are summarized for each option addressing a particular waste stream or source along with the written documentation developed in the phase of the audit effort. Table 4 is a sample table illustrating the approach used to develop such a summary table.

Presentation and Joint Review of Options with Plant Personnel

Following the technical and economic evaluation of the selected options by the audit team, these options are prepared in the form of a Preliminary Audit Report to be submitted to appropriate plant personnel. Each option in the Preliminary Audit Report should be well described in terms of the technical rationale and projected "order of magnitude" cost estimates. Cost estimates are of particular importance to plant personnel who have to deal with tight operating budgets and need to have some idea of the cost of implementing a seemingly attractive option. In this regard, calculation of "payback period" will provide a quick indication of the economic viability of the proposed option. Cost estimates are also of importance to the options that belong to the category of good operating practices. Availability of preliminary cost data along with the presentation of this category of option circumvents quick dismissal of these options as "trivial" by a technology-oriented plant engineer.

The plant personnel are asked to review the Preliminary Audit Report and independently rate each proposed option, revise them based on their assessment, and come up with any additional options that they see as applicable.

The review process culminates in the joint meeting where the audit team presents the proposed options one by one. Presentation ideally includes detailed discussion of rationale and reasons for selected ratings. The plant engineers then present their critique or comment. The discussion should conclude with a revised rating which would be acceptable to both sides. If such conclusion cannot be reached, a further course of action must be well outlined.

The objective of the meeting is to obtain an agreement on the ratings of various proposed options -- these ratings are analyzed and used to rank all of the options with the aim of selecting those that warrant further evaluation by the plant. It also may happen that the plant personnel may come up with new options or that such options may result from the joint discussion.

As a result of the meeting, all appropriate revisions of the options presented in the Preliminary Audit Report are made in preparation for issuing a Final Audit Report.

Final Audit Report

The Final Audit Report should contain, at a minimum, the following sections:

1. Facility and process description.
2. Description of waste stream(s) origin, composition, and quantities.
3. Detailed description of all waste minimization options considered including simplified schematics of revised process flows (if appropriate) and lists of any new process equipment required.

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Final Audit Report

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1. Facility and process description.

2. Description of waste stream(s) origin, composition, and quantities.

3. Detailed description of all waste minimization options considered including simplified schematics of revised process flows (if appropriate) and lists of any new process equipment required.

4. Detailed evaluation of technical feasibility and potential benefits of all waste minimization options considered, together with their preliminary economics (capital and operating costs, estimated pay back period), and final rankings (based on audit team findings and host plant engineers' evaluations).

5. Recommendations including any research and development efforts needed to further evaluate the recommended options.

WASTE AUDITING - SOME DO'S AND DON'TS

Some of the most important lessons learned in the initial audits relate to the human element of the audit process, i.e., to the interaction between the audit team and the host facility personnel.

Obviously, it is vital that host facility personnel become and remain active participants through the audit process. Some nontechnical skills of the audit team personnel, and particularly of the audit team leader, were found to be extremely valuable here.

The audit team leader must be an effective and aggressive communicator as well as a technical expert, because this individual must serve as a facilitator for the audit team and host facility personnel alike. A reserved and low key attitude and behavioral style by the audit team could lead to a passive or disinterested stance by the host facility personnel.

The pre-audit activities, particularly the pre-audit site visits, were found to be extremely important in facilitating the audit process. When the audit team spent a little more time getting to know the host facility staff and the functioning of the organization (as in the pre-audit site visit), the audit process moved more smoothly. The audit team found it easier and faster to acquire needed data, because the members knew the operation and the people a little better, and the level of cooperation by plant staff was improved.

The experience gained in these audits also led to a modification of the audit method. The modified approach requires host facility personnel to independently develop ratings for each of the waste reduction options under consideration. The audit team's ratings for the options and the host facility's independent ratings can then be reviewed and reconciled in a group session. The initial approach of having the host facility personnel merely review and discuss the audit team's ratings following the presentation of the option ratings resulted in relatively casual, uninvolved behavior by the host facility staff.

In summary, a WMA (and a WM program as a whole) requires that audit team members exhibit effective communications and human interaction skills, as well as technical insight and engineering ability. A successful WM audit program thus requires success in both technical and human relations areas.

CASE STUDIES

The EPA/Office of Research and Development/Hazardous Waste Environmental Research Laboratory, Cincinnati, Ohio (HWERL) has supported ten projects to date in which the WMA procedure have been used. Table 5 identifies these projects.

In 1986 these audits focused on four generic hazardous wastes: corrosives, heavy metals, spent solvents and cyanides. In 1987, the audits focused on some of the listed F and K wastes in the EPA/ORD list of top priority wastes. In this paper we have summarized the results of four projects carried out at the following facilities:

a) Speciality steelmaking complex (corrosive waste)
b) Ceramic capacitor manufacturer (solvent waste)
c) Mercury cell chloralkali plant (K071 waste)
d) DOD installation (F002, F004 and F006 waste)

Corrosive waste

The corrosive waste stream that was the subject of this WMA was pickling waste (RCRA #K062) generated by a stainless steel pickling facility in an electric arc furnace (EAF) steelmaking complex in the East. The waste stream results from a process in which annealed stainless steel is treated in a Kolene bath at 800 F (427 C) followed by a nitric-hydrofluoric acid pickle.* The process produces a highly alkaline Kolene rinse water and an acidic combined spent pickle liquor and rinse water stream from the HF/HNO_3 pickling operation. Figure 4 presents a block flow diagram of the operation.

During the audit phase of this study, process and waste treatment operations were intensively studied by the audit team. The use of various potential source reduction and recycling options was reviewed with plant personnel. The plant already recycles part of the spent acid mixture to the pickling line, thus reducing fresh acid use. Based on the audit team's evaluation and discussions with plant personnel, there did not appear to be any other significant source reduction options available.

With respect to recycling options, the present neutralization treatment of the combined pickling line wastewater stream (K062) generates a mixed sludge for which there is essentially no potential for reuse. The audit team determined that the raw waste, however, does contain a constituent (fluoride ion) that could be converted into a useful product-calcium fluoride (fluorspar). The EAF facility at this steelmaking complex presently purchases about 1,000 tons per year (907 metric tons per year) of fluorspar for use as a furnace flux material in the steelmaking process. Current cost for metallurgical grade fluorspar (approximately 80 percent calcium fluoride) for flux use is $100 per ton ($110 per metric ton) at the plant. The audit team proposed a waste minimization option for recovery of calcium fluoride wherein the combined wastewater stream at pH 2 (excluding the treated Kolene waste) is treated with slaked lime at a controlled rate so that pH 2.5 is not exceeded. Calcium fluoride will precipitate selectively, and at this pH, fluoride solubility data indicate that a level of 65 ppm dissolved fluoride will be achieved. With about 1,100 ppm dissolved fluoride in the raw wastewater, approximately 95 percent of the fluoride will precipitate. This is equivalent to about 1,300 tons per year (1,179 metric tons per year) of calcium fluoride potentially recoverable (based on 330 days per year operation), which more than equals the annual consumption of calcium fluoride (fluorspar flux) in the EAF operation. Hydroxides of iron, nickel, and chromium are all highly soluble at pH values below 3.0 and thus would not be expected to co-precipitate with the calcium fluoride.

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* Kolene is a mixture of molten sodium and potassium hydroxides.

The combined spent pickle liquor and rinse water discharge would be treated in the same waste acid neutralization system now used to generate the neutralized non-hazardous solids discharged off-site and NPDES effluent to the outfall. However, the neutralization would be done in series in two stages, thereby effecting the recovery of a reasonably pure calcium fluoride in the first stage. After the first stage of neutralization, the presently treated Kolene waste would be combined with the partially neutralized waste pickle liquor/rinse water stream. The combined stream would then be neutralized and discharged to the outfall. Figure 5 is a block flow diagram of the proposed fluorspar recovery process.

If this option were to be put into operation, not only would the generation rate of sludge from K062 treatment be reduced (resulting in a saving in off-site sludge disposal costs), but a substantial potential savings in chemical purchases could be made. A preliminary economic analysis of this option (summarized in Table 6) confirmed these points. Offsite disposal cost of the sludge resulting from K062 neutralization could be reduced about 30 percent and potential overall savings resulting from option implementation were estimated as $168,000 annually (including $100,000 savings in purchased fluorspar, and $68,000 savings in the cost of offsite sludge disposal). Following a review of the audit team analysis, plant personnel agreed that this was a worthwhile option and planned to give serious consideration to implementation of this option.

Solvent Waste

The facility chosen for the solvent waste WMA is a major manufacturer of multilayer ceramic capacitors used primarily by the telecommunications and military electronic industries. Production operations are performed in two separate buildings located within close proximity to each other. Ceramic materials are formulated in an annex building and then transferred to the Main Facility where the capacitors are formed. Various finishing operations are performed at both building.

Major operations are depicted schematically in the block flow diagram (Figure 6).

The solvent wastes are generated mainly by various equipment cleaning operations:

- ball mill cleaning and off-spec slurry disposal;
- cleaning of the transfer pots;
- off-spec slurry disposal, cleaning and flushing of the slurry application system;
- general cleaning;
- still bottoms from the on-site TCA still.

The solvents used for cleaning include 1,1,1-trichlorethane (TCA), RM-513 (a proprietary solvent), and isopropyl alcohol (IPA).

Each main solvent cleaning operation was scrutinized by the audit team so as to develop a list of options that would reduce or eliminate waste generation at the source. The focus was mainly on recycling of spent cleaning solvent; such an approach was deemed as the most effective short-term option. The long-term solutions (e.g., development of non-solvent formulations) could not be meaningfully addressed in this study.

Following discussion with facility personnel several of the recycling options developed by the audit team were selected for further investigation based on their high potential for waste reduction. the options evaluated in detail were:

- Ball Mill and Slurry Application Wastes: Segregate and recycle RM-513 based off-spec slurry.

- Ball Mill, Transfer Pots, and Slurry Application Wastes: Segregate, standardize, and recycle cleaning solvents.

- Slurry Application Wastes: Segregate and recycle RM-513 flushing solvent.

- Slurry Application Wastes: Convert application system filters to bag/wire mesh type.

- General Cleaning Wastes: Segregate and recycle isopropyl alcohol waste.

- TCA Primary Recovery Wastes: Install secondary recovery system.

Figure 7 partially depicts a proposed scheme for segregation and recycle of cleaning solvents based on the options indicated. Table 7 summarizes the results of the economic feasibility analysis performed for each of these options.

Many of the options discussed above rely on the use of a small batch still for solvent recovery. Since the still operates in a batch mode, all of these waste streams can be separately processed in the same unit. By dividing the capital cost for one system by the savings resulting from implementation of the four options indicated in Table 7, the overall payback period is calculated at 0.9 years, as opposed to periods ranging from 2.2 to 4.8 years for each option individually. By implementation of the above-mentioned measures in this mode, the facility can reduce solvent waste generation by 54 percent (5,810 gallons per year) at an estimated annual savings of $30,190. In summary, the economic and technical feasibility for on-site reclamation of cleaning solvent is demonstrated. The plant personnel have concurred with this analysis and are proceeding to install the type of still described in the audit.

Listed Waste K071

Listed waste K071 is generated by mercury cell chloralkali plants. These plants produce chlorine, with sodium hydroxide (NaOH) and potassium hydroxide (KOH) as co-products depending on whether sodium chloride (NaCl) or potassium chloride (KCl) brines are used as feed to the electrolytic cells used in the process. The two listed K wastes generated by this industry are defined in 40CFR 261.32 as follows:

- K071: Brine purification muds from the mercury cell process in chlorine production, where separately prepurified brine is not used

- K106: Wastewater treatment sludge from the mercury cell process in chlorine production.

This case study presents the results of the WMA on K071 waste.

The mercury cell plant which acted as the host site in this case study is located in the Southeast and has a name plate capacity of 138,000 metric tons of chlorine per year. The plant operates two parallel production lines - one producing 310 metric tons per day of NaOH and the other producing 246 metric tons per day of KOH. The plant generates approximately 5,000 tons per year of K071 waste (mercury-bearing saturator insolubles and brine purification wastes) and about 20 tons per year of K106 waste (mercury-bearing wastewater treated sludge). All of these wastes are currently sent offsite to a hazardous waste landfill. Figures 8 and 9 are simplified schematics of the plant and brine purification operations, respectively.

While K071 is a large-volume waste, the audit team determined that the mercury level (typically in the 25 ppm range) was too low to permit economic recovery and recycle of this pollutant thus ruling out recycle/reuse as a WM option. Prepurification of the NaCl brine to eliminate one of the main sources of this waste (the brine saturator insolubles) proved to be an uneconomical source reduction option. A total of seven source reduction options for this waste were considered by the audit team. Six of these had to be ruled out because of unfavorable economics and/or unproven technical feasibility of the process. The seventh option (replacement of the mercury electrolytic cells with the newer membrane cell technology - the industry's process of choice currently) appeared to have an attractive payback period (approximately 2 years) primarily due to significantly more economical chlorine production technology and to a much smaller extent, elimination of the K071 hazardous waste disposal problem. However, use of membrane cell technology requires the plant to invest approximately $20 million for installation of this option, making it unlikely to be considered seriously at this time.

While K071 waste treatment is not considered a WM option, the audit team determined that the plant has several technically viable treatment options with reasonable payback periods available. One or more of these options was the potential for detoxifying the K071 waste thus allowing it to be delisted by EPA with the resulting non-hazardous waste being able to be placed in a local sanitary landfill. The plant is studying these alternatives at the present time. Figures 10 and 11 depict two treatment options evaluated by the audit team which appear to be technically feasible and have attractive payback periods (<3 years).

Table 8 summarizes all of the K071 waste reduction and treatment options studied by the audit team. One source reduction option (highly capital intensive) and two treatment options meet the criteria for technical and economic feasibility (at the preliminary evaluation stage) at this time. The plant is giving serious consideration to a significant revision in the present K071 waste treatment and disposal operation (as must all of the 14 mercury cell chloralkali plants faced with this problem) due to the pending imposition of the EPA Best Demonstrated Available Technology (BDAT) requirements for disposal in hazardous waste landfills by the summer of 1988.

Listed Wastes F002, F004, and F006

A DOD installation in the South, a portion of whose facilities is devoted to the rehabilitation of worn Army tanks was studied in a WMA for the reduction of F002, F002, and F006 wastes. These listed F wastes are partially defined in 40 CFK 261.32 as follows:

- F002: Spent halogenated solvents including methylene chloride,
- F004: Spent non-halogenated solvents including cresols and cresylic and;
- F006: Wastewater treatment sludges from electroplating operations

Two areas of the DOD installation generate these wastes:

a) tank part paint stripping facilities using methylene chloride solvent formulations (containing phenolic-type constituents to enhance solvent action), generate F002 and F004 wastes.

b) cleaned tank part cadmium and chromium plating facilities generate F006 waste.

Solvent wastes are generated in three buildings at the facility and include:

- Approximately 20,000 gallons per year of spent solvent and about 60-55 gallon drums of paint sludge are generated in the paint stripping operations and sent offsite for hazardous waste disposal.
- Wastewater from stripped parts rinsing operations sent to the onsite wastewater treatment plant (total amount unknown).

The audit team studied possible source reduction and recycle/reuse options for these wastes. The focus was primarily on ways to prolong the life of the paint stripping solvents as the most effective short-term option. The long term waste reduction options, i.e., development of non-solvent formulations and other paint removal techniques, could not be meaningfully addressed in this study.

The most promising source reduction options for paint stripping solvent waste reduction were:

- Continuous centrifugation of the paint stripping solvent to remove paint sludge as it is generated thus preventing buildup of this sludge in the stripping tanks and significantly extending the life of the solvent.

- As an alternative to continuous centrifugation of the solvent, continuous 2-stage basket/cartridge filtration of the solvent to prevent paint sludge buildup.

Based on successful implementation of either of these options, it was assumed that solvent life could be extended to one year prior to replacement.* Each of the six main paint stripping solvent tanks at the facility would be equipped with either a solid-bowl type centrifuge or a basket/cartridge type 2-stage filter. Table 9 summarizes the results of the preliminary technical and economic feasibility study of these two options. Annual waste solvent disposal cost would be cut in half (approximately $50,000 per year savings) if either of these two options were adopted with payback periods ranging from 0.5 to 0.7 year.

Electroplating operations at the DOD installation are conducted in one building and include cadmium plating of miscellaneous cleaned and remachined (where required) tank parts from cadmium/cyanide (Cd/CN) solutions in either an automatic barrel plating line or a manual rack plating line. Chromium (Cr) plating of appropriately prepared tank parts is conducted in a rack plating line. Both plating operations are fairly standardized. Simplified schematics of the three plating operations are shown in Figures 12-14.

The facility has been experiencing significant problems in meeting NPDES permit limitations for Cd and CN in the treated wastewater discharge. Thus, the audit team focused primarily on waste reduction options which could reduce or eliminate Cd and CN levels in the raw waste (principally rinsewaters from both Cd plating lines). Approximately 2,000 gallons per day of these wastewaters typically containing 20 mg/l of Cd and 25 mg/l CN are discharged from the electroplating facility. About 35,000 gallons per day of Cr-bearing waste averaging 110 to 120 mg/l Cr are also discharged from this facility.

A study of the electroplating operations that generate F006 waste (including discussions between the audit team and plant personnel), led the audit team to develop a total of five WM options for Cd/CN plating-related waste and two WM options for Cr plating-related waste. These options include commercially demonstrated processing techniques designed to minimize or eliminate Cd, Cr and CN levels in the rinsewater wastes as well as reducing the amounts of wastewater, and are summarized in Table 10. One proposed source reduction option: electrolytic reverse current destruction of CN (both simple and complexed) in the still rinse tanks of the two Cd plating lines during the plant downtime period, is currently being evaluated at the facility. One proposed recycle/reuse option, recovery of Cd from these same still rinse tanks, has since been implemented and appears to have resulted in the facility being able to consistently meet Cd limit in their NPDES permit.

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* [illegible] small scale test by [illegible] trifuge vendor on a sample of spent solvent heavily loaded [illegible] paint sludge, indicated that clear solvent could be produced by this technique.

In summary, successful implementation of appropriate combinations of these WMA options could result in the DOD installation being able to achieve EPA delisting of the F006 wastewater treatment sludge. Payback periods for the incremental investment involved range from 6 months to 1.9 years. Savings in the present F006 waste disposal costs could amount to $120,000 annually if the F006 waste can be delisted.

CONCLUSIONS

The results of the four WMAs presented in this paper point to the waste minimization audit procedure as being a useful tool for reducing waste generation. It provides a structure that provides for in-depth investigation while encouraging creativity. Hazardous waste generators would be well advised to incorporate WMAs into their overall environmental program since the results are not only good for the environment but can contribute to substantial financial savings.

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DISCLAIMER

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Table 1. Waste Minimization Program Elements

Program phase	Job plan* phase	Elements
I. Initiation/ Planning		• Secure commitment/authority
		• Establish goals
		• Establish organization
II. Pre-Audit	Information	• Preparation for the audit
		• Pre-audit inspection
		• Waste stream selection
III. Audit	Creative	• Facility inspection
		• Generate comprehensive set of WM options
	Judgment	• Options evaluation
		• Selection of options for feasibility analysis
IV. Post-Audit	Development	• Technical and economic feasibility analysis
	Recommendation	• Report preparation
V. Implementation		• Selection of options for implementation
		• Design, procurement, construction
		• Startup
		• Performance monitoring

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* Term adopted from value management program.

Table 2. Recommended Waste Minimization Audit Procedure

Program phase	Activities	Product
Pre-Audit	1. Preparation for the audit	• needs list/ inspection agenda
	2. Pre-audit meeting and inspection	• notes
	3. Waste stream selection	• process description • waste descripton with rationale for selection
Audit	4. Audit inspection	• notes
	5. Generation of a comprehensive set of WM options	• list of proposed options with written rationale
	6. Options evaluation and selection for feasibility analysis	• list of selected options • options ratings by audit team and by plant personnel • options interim report
Post-Audit	7. Technical and economic feasibility analysis	• study or budget grade estimates of capital and operating costs; profitability analysis
	8. Final report preparation	• final report with recommendations

Table 3 Waste Minimization Audits. Generalized List of Information Sources

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- Design process flow diagrams (PFD)
- Heat and material balances
  - production processes
  - pollution control systems
- Equipment list
- Piping and instrument diagrams (P&ID)
- Materials application diagrams
- Plot and elevation plans
- General arrangement drawings
- Piping layout drawings
- Operation manuals, process descriptions
- Permits and/or permit applications
- Emission inventories
- Hazardous waste manifests
- Annual (or biennial) reports
- Waste assays
- Operator data logs, batch sheets
- Materials purchase orders
- Environmental audit/review reports
- Production Schedules
- Organization chart

Table 4. SUMMARY OF SOURCE CONTROL METHODOLOGY FOR THE A/B POWDER FORMULATION PROCESS ILLUSTRATION OF DEVELOPMENT OF OPTIONS RANKING

Waste source	Control methodology	Waste reduction effectiveness	Extent of current use	Future application potential	Fraction of total waste	Current reduction index	Future reduction index
Weighing operation	1. Return empty containers	2	0	2		0.00	0.25
	2. Use preweighed containers	2	0	4		0.00	0.50
	3. Use drum covers	2	2	1		0.25	0.06
	Overall	2.00	0.67	2.33	0.10	0.25	0.50
Wet grind loading and unloading	1. Use plastic funnel/collar on unit	2	0	4		0.00	0.50
	2. Use smaller trays, manual operation	2	0	2		0.00	0.25
	3. Place trays on rack, walk-in oven	2	0	2		0.00	0.25
	4. Use elevator table on rack, walk-in oven	1	0	1		0.00	0.06
	5. Install roller conveyer under valve	1	0	1		0.00	0.06
	6. Install fail-close valve on discharge	2	0	3		0.00	0.38
	7. Pump slurry into trays over at oven	2	0	1		0.00	0.13
	8. Reduce cleaning frequency	3	0	3		0.00	0.56
	9. Bypass dry grinding unit	2	0	4		0.00	0.50
	Overall	1.89	0.00	2.33	0.45	0.00	0.56
Dry grind loading and unloading	1. Use plastic funnel/collar on unit	2	0	4		0.00	0.50
	2. Do not load while unit is operating	3	4	0		0.75	0.00
	3. Inspect all seals regularly	2	3	2		0.38	0.06
	4. Use drum covers	2	2	3		0.25	0.19
	5. Bypass dry grinding unit	4	0	4		0.00	0.90
	Overall	2.60	1.80	2.60	0.45	0.75	0.90
All sources	All methods				1.00	0.58	0.71

Table 5. EPA/ORD WMA Projects Carried Out to Date

WMA No	Project Phase	Waste Stream Audited	Host Site Description	Title of Audit Report*
1	I	Heavy metals	Electric arc furnace (EAF) manufacturing of specialty steels	Waste Minimization Audit Report: Waste Minimization Audits at Generators of Corrosive and Heavy Metal Wastes
2	I	Corrosives	EAF stainless steels pickling operation	
3	I	Solvents	Naval aircraft service complex	Waste Minimization Audit Report: Case Studies of Minimization of Solvent Waste from Parts Cleaning and from Electronic Capacitor Manufacturing Operations
4	I	Solvents	Ceramic capacitor manufacturer	
5	I	Cyanide	Naval aircraft service complex	Waste Minimization Audit Report: Case Studies of Minimization of Cyanide Waste from Electroplating Operations
6	I	Cyanide	Job plating shop	
7	II	K071 (Brine purification waste)	Mercury cell chloralkali plant (Plant No. 1)	Waste Minimization Audit Report: Case Study of Minimization of K071 and K106 wastes at Two Mercury Cell Chloralkali Plants
	II	K106 (Wastewater treatment sludge)	Mercury cell chloralkali plant (Plant No. 1)	
8	II	K071 (Brine purification water)	Mercury cell chloralkali plant (Plant No. 2)	Waste Minimization Audit Report. Case Study of Minimization of K071 and K106 Wastes at Two Mercury Cell Chloralkali Plants
	II	K106 (Wastewater treatment sludge)	Mercury cell chloralkali plant (Plant No. 2)	
9	II	F006 (cyanide plating bath waste)	Army tank rehabilitation facility	Waste Minimization Audit Report. Case Study of Minimization of F006 Cyanide Plating Bath Waste and F002, F004 Solvent Wastes at an Army Tank Rehabilitation Facility.
	II	F002, F004 (solvent wastes)	Army tank rehabilitation facility	
10	II	K048-K052 (Petroleum refinery wastes)	Petroleum refinery	Waste Minimization Audit Report: Case Study of Minimization of an Oil Refinery Sulfur Recovery Plant Waste

* All reports are currently in publication.

Table 6. Summary of Preliminary Economic Feasibility Study of Recycling Option for Corrosive Waste

Item	Cost
• Total capital cost for additional processing facilities and existing plant modifications.	$300,000
• Annual operating cost	$46,000/yr
• Savings due to replacement of purchase fluorspar	$100,000/yr
• Savings due to lower cost of offsite waste disposal	$68,000/yr
• Total potential savings	$168,000/yr
• Estimated payback period	2.5 years
• Estimated internal rate of return (based on an economic life of 5 years)	28 percent

Solvent Waste WM Audit

TABLE 7 - ECONOMICS OF PROPOSED WM OPTIONS

Waste Source	Minimization Option	Waste Reduction Gallon/Year	Waste Reduction Percent	Net Annual Savings	Capital Costs	Pay-back Years
Ball Mills and Transfer Pots	(*) Segregate and Recycle RM-513 Wastes.	720	28.8	$6,040	$25,750	4.3
	Standardize Solvent Used and Recycle	2,150	86.0	$19,130	$25,750	1.3
Slurry Application Systems	(*) Segregate and Recycle Cleaning Waste.	725	96.7	$5,400	$25,750	4.8
	Use Bag Type Filters.	- - -	90.0	$1,260	$23,950	19.0
	Use Metal Mesh Type Filters.	- - -	100.0	$6,660	$9,830	1.5
General Cleaning With Isopropyl Alcohol	(*) Segregate and Recycle Cleaning Waste.	2,350	50.0	$11,650	$25,750	2.2
TCA Primary Recovery	(*) Install a Secondary Recovery System.	2,015	73.3	$7,100	$25,750	3.6
All Solvent Waste Sources Shown Above	Use a Common Batch Still for (*) Methods.	5,810	54.3	$30,190	$25,750	0.9

Table 8. Summary of Postulated Options for Minimization of Listed Waste K071

Option	Description	Type of option	Advantages	Disadvantages	Potential savings ($/yr)
A	Reduction of depleted brine dissolved sulfate level to minimize saturator insolubles generation	Source reduction	Reduce generation rate of saturator insolubles portion of K071 waste by as much as one-third. Save significant labor cost currently involved in periodic cleanout of saturators.	Depleted brine side stream treatment needed to reduce dissolved sulfate results in excessive precipitant cost as well as large additional generation of mercury-contaminated wastes.	
B	Use of prepurified salt feed stock	Source reduction	Essentially complete elimination of mercury-contaminated K071 waste generation in NaOH production.	Unacceptable economics.	
C	Use of solar salt as a feed stock	Source reduction	Significant reduction of mercury-contaminated K071 generation in NaOH production.	Unacceptable economics.	
D(1)(a)	Removal of mercury from depleted brine prior to brine resaturation, using sulfide precipitation with disposal of mercury sulfide waste	Source reduction	Essentially complete elimination of mercury-contaminated K071 waste generation in NaOH production.	Commercially unproved process; creation of another K071 waste, unacceptable economics.	

Table 8 (Continued)

Option	Description	Type of option	Advantages	Disadvantages	Potential savings ($/yr)
D(1)(b)	Removal of mercury from depleted brine prior to brine resaturation using sulfide precipitation, followed by mercury retorting and recovery from mercuric sulfide waste	Source reduction	Same as in D(1)(a).	Commercially unproven process; unacceptable economics.	-
D(2)	[illegible] of mercury from depleted brine prior to brine resaturation using ion exchange resin	Source reduction	Same as D(1)(a).	No commercially available resin available for handling harsh depleted brine environment without extensive pretreatment for chlorine removal; limited resin capacity and allowable brine flow rate require very large resin beds (unacceptable economics).	-
E	Conversion of mercury electrolytic cells to membrane electrolytic cells	Source reduction	Complete elimination of all mercury-bearing streams results in elimination of K071 and K106 wastes; preliminary economics indicate acceptable payback period (~2 years). Membrane technology commercially proven.	Detailed feasibility study using definitive base costs may show much worse payback than preliminary estimate. Space requirements for auxiliary equipment may be unavailable.	600,000

Table 8. (Continued)

Option	Description	Type of option	Advantages	Disadvantages	Potential savings ($/yr)
(1)	Use of a washing process to reduce the level of mercury in the K071 saturated insolubles below 12 ppb, enabling this waste to be delisted	Treatment	Simple, commercially-proven process that would allow delisting of a large portion of K071 waste. Favorable payback period (~2 years). Space availability at plant is not a problem.	Potential delay in achieving EPA delisting because of lengthy procedure involved.	380,000
(2)	Same as (1) for saturator insolubles coupled with NaSH treatment process for brine purification muds, enabling delisting of the entire K071 waste stream	Treatment	Same as in (1) for saturator insolubles; addition of process for brine muds still shows favorable payback period (2.3 years). Space availability at the plant for a combined treatment process is not a problem.	Sulfide treatment step for brine purification muds is commercially unproven. Lack of proven treatment process could delay up EPA delisting of the entire stream until adequate body of process data is available.	325,000
(3)	Same as (1) for saturator insolubles coupled with Vulcan Treatment Process for brine purification muds, enabling delisting of the entire K071 waste stream	Treatment	Same as (1) for saturator insolubles. Vulcan process is commercially proven and is expected to be BDAT for K071 waste. Space availability at plant for combined treatment process is no problem.	Economics of Vulcan process for combined NaCl and KCl brine stream purification muds appears unfavorable at this time. Vulcan process may also generate higher TDS in effluent from Plant No. 1 than State will allow.	-

Table 9. Tabulated Projected Costs and Required Site Modifications: WM Options for DOD Installation F002 and F004 Wastes

WM Option[1]	Waste source	Option description	Proposed equipment modifications	Estimated installed cost ($)	Estimated annual direct operating cost[2] ($/yr)	Required site modifications	Payback period (years)
(1)	Waste paint stripping solvent disposal	Continuous removal of paint sludge from solvent (using a solid bowl centrifuge. Solvent replaced annually.	Add a pump and solid bowl centrifuge to each of the six paint stripping solvent tanks; unit operates at about 5 gpm flow rate.	50,000	5,000	Adequate floor space is available in front of each of these stripping tanks to permit installation without major existing equipment relocation	0.5
(5)	Waste paint stripping solvent disposal	Continuous removal of paint sludge from solvent (using a two-stage filtration unit). Solvent replaced annually.	Add a pump and two-stage filtration unit to each of the six paint stripping solvent tanks (first stage is basket type filter for large pieces and second stage is a porous metal filtration cartridge for micron-size particles.	60,000	9,000	Adequate floor space is available in front of each of these stripping tanks to permit installation without major existing equipment relocation	0.67

[1] All options shown are source reduction options.

[2] Other than the cost of replacing spent paint stripping solvent, which is estimated separately.

Table 10 Tabulated Projected Costs: WM Options for DOD Installation F006 Wastes[1]

WM option	Waste source	Option type	Option description	Proposed equipment modifications	Estimated installed cost ($)[1]	Estimated annual operating cost ($/yr)
(a)(1)	Cd/CN Barrel Plating Line	Source reduction	Use of electroclean rinse waters as feed to pickling rinse water tank	Water piping and pump	$ 1,000	$ 500
(a)(2)	Cd/CN Manual Plating Line	Source reduction	Use of electroclean rinse waters as feed to pickling rinse water tank	Water piping and pump	1,000	500
(b)(1)	Cd/Cn Barrel Plating Line	Source reduction	Destruction of cyanides in still rinse tank	Insertion of SS cathodes and anodes in still rinse tank and operation in a CN destruction mode during plating line downtime	2,000	10,000
(b)(2)	Cd/Cn Manual Plating Line	Source reduction	Destruction of cyanides in still rinse tank	Insertion of SS cathodes and anodes in still rinse tank and operation in a CN destruction mode during plating line downtime	2,000	10,000
(c)(1)	Cd/Cn Manual Plating Line	Source reduction	Improved dragout recovery; drain board, spray/fog rinsing nozzles over plating tank	Add drain board between Cd plating tank and still rinse tank; install spray/fog rinse	1,500	1,000
(c)(2)	Chromium Manual Plating Line	Source reduction	Improved dragout recovery; drain board, spray/fog rinsing	Add drain board between Cr plating tank and still rinse tank; install spray/fog rinse nozzles over plating tank	1,500	1,000

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Table 10. (Continued)

WM option	Waste source	Option type	Option description	Proposed equipment modifications	Estimated installed cost ($)[1]	Estimated annual operating cost ($/yr)
(d)	Both Cd/CN Plating Lines	Recycle/reuse	Evaporation of Cd/CN rinse water discharge and recycle to both plating lines in appropriate quantities to maintain individual plating bath water balances	Install evaporation unit and auxiliaries in Building 114 basement near Cd/CN waste sump	79,000	27,000
(e)(1)	Cd/Cn Barrel Plating Line	Recycle/reuse	Plating out of cadmium in still rinse tank	Insertion of SS cathodes and anodes in still rinse tank to operate in a Cd plating mode during plating line downtime	Use the same equipment as in (b)	20,000
(e)(2)	Cd/Cn Manual Plating Line	Recycle/reuse	Plating out of cadmium in still rinse tank	Insertion of SS cathodes and anodes in still rinse tank to operate in a Cd plating mode during plating line downtime	Use the same equipment as in (b)	20,000
(f)	Chromium Manual Plating Line	Source reduction	Improved dragout recovery: replacement of running rinse tank with spray chamber	Install suitable banks of spray nozzles in empty running rinse tank	5,000	2,000
(g)	Chromium Manual ing line	Source reduction	Reduction of chromium metal losses from hood vents over plating tanks	Add layer of plastic balls on surface of chromium plating tanks	Nil	Nil

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[1] Order of magnitude costs (± 50 percent accuracy)

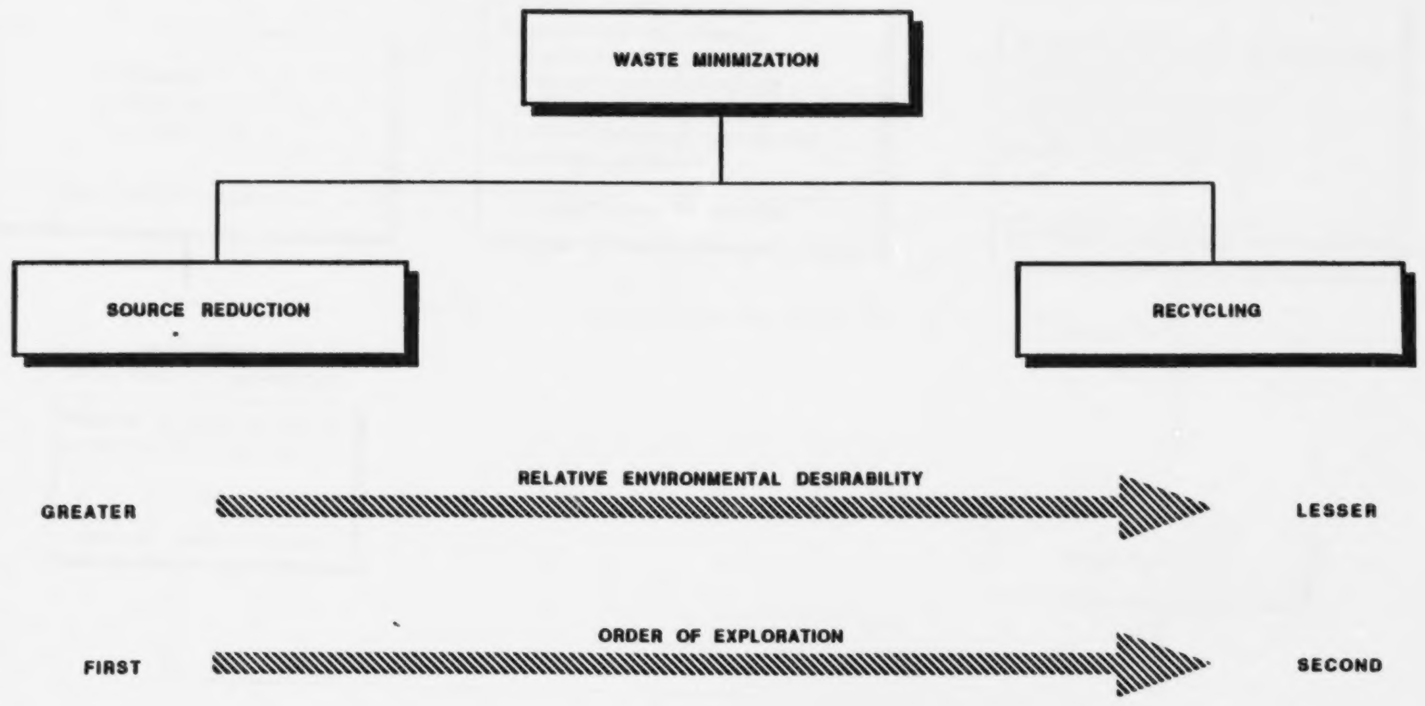


FIGURE 1. COMPONENTS OF WASTE MINIMIZATION, THEIR HIERARCHY AND DEFINITIONS

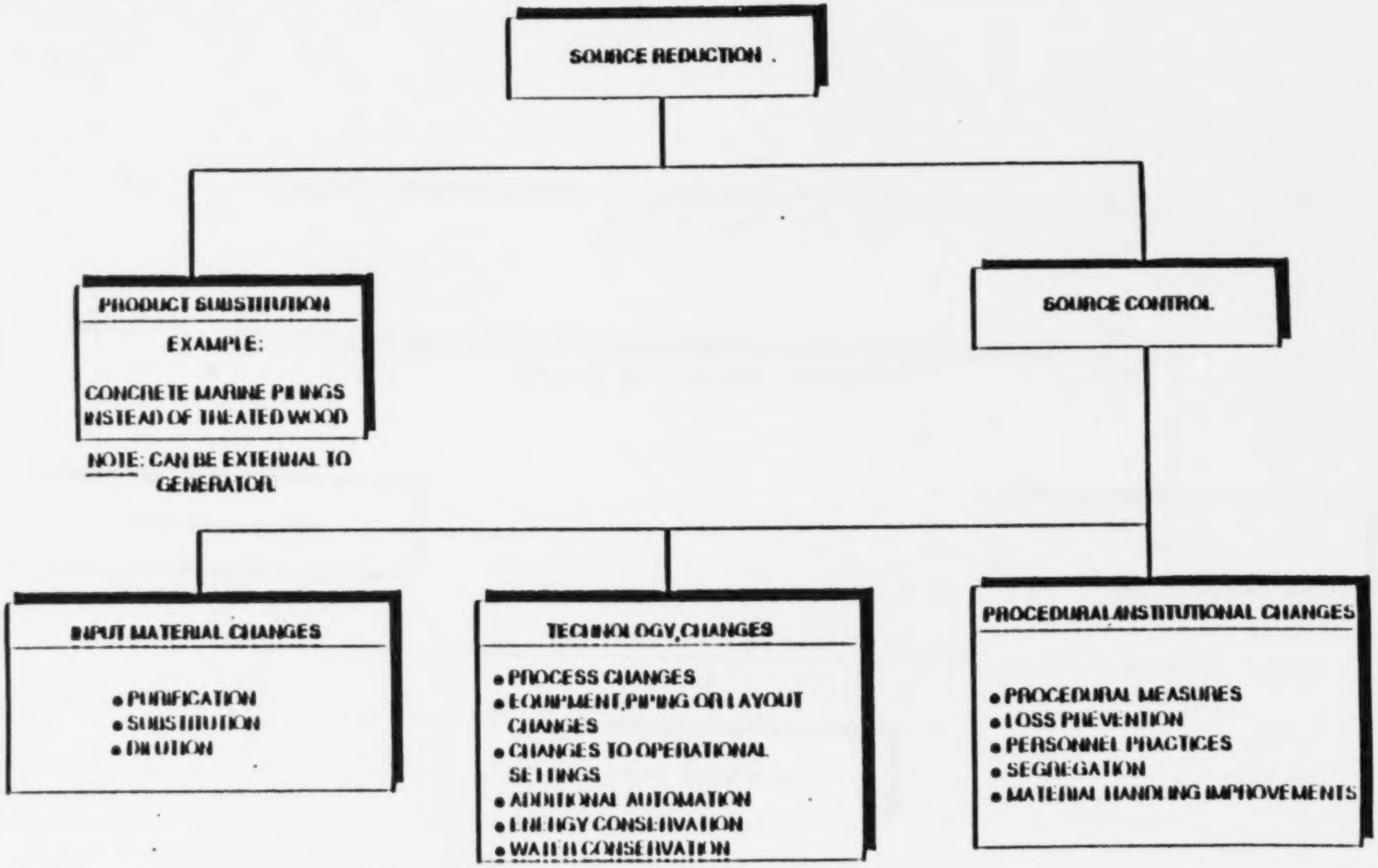


Figure 2. Elements of source reduction

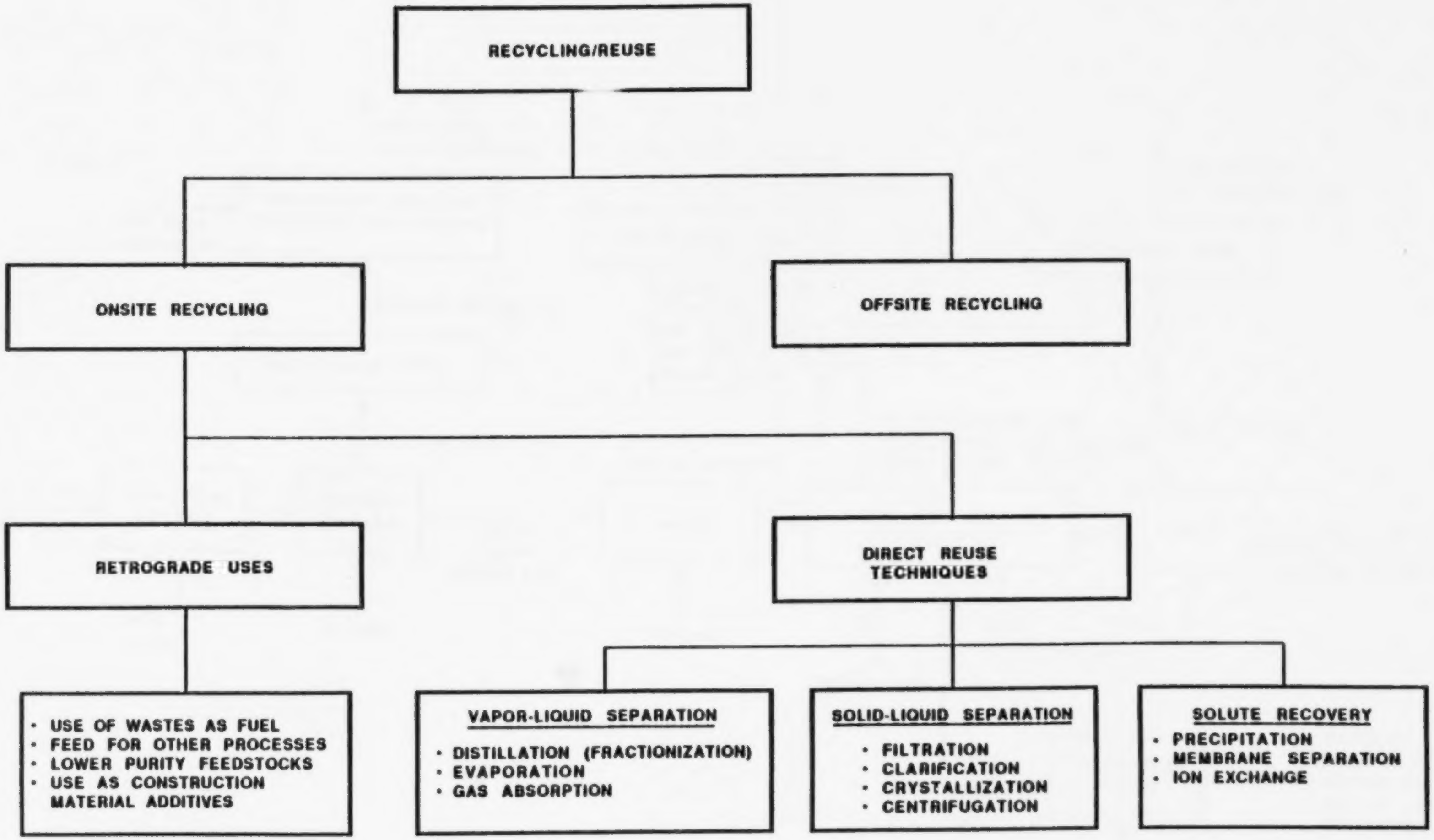


FIGURE 3. ELEMENTS OF RECYCLE/REUSE

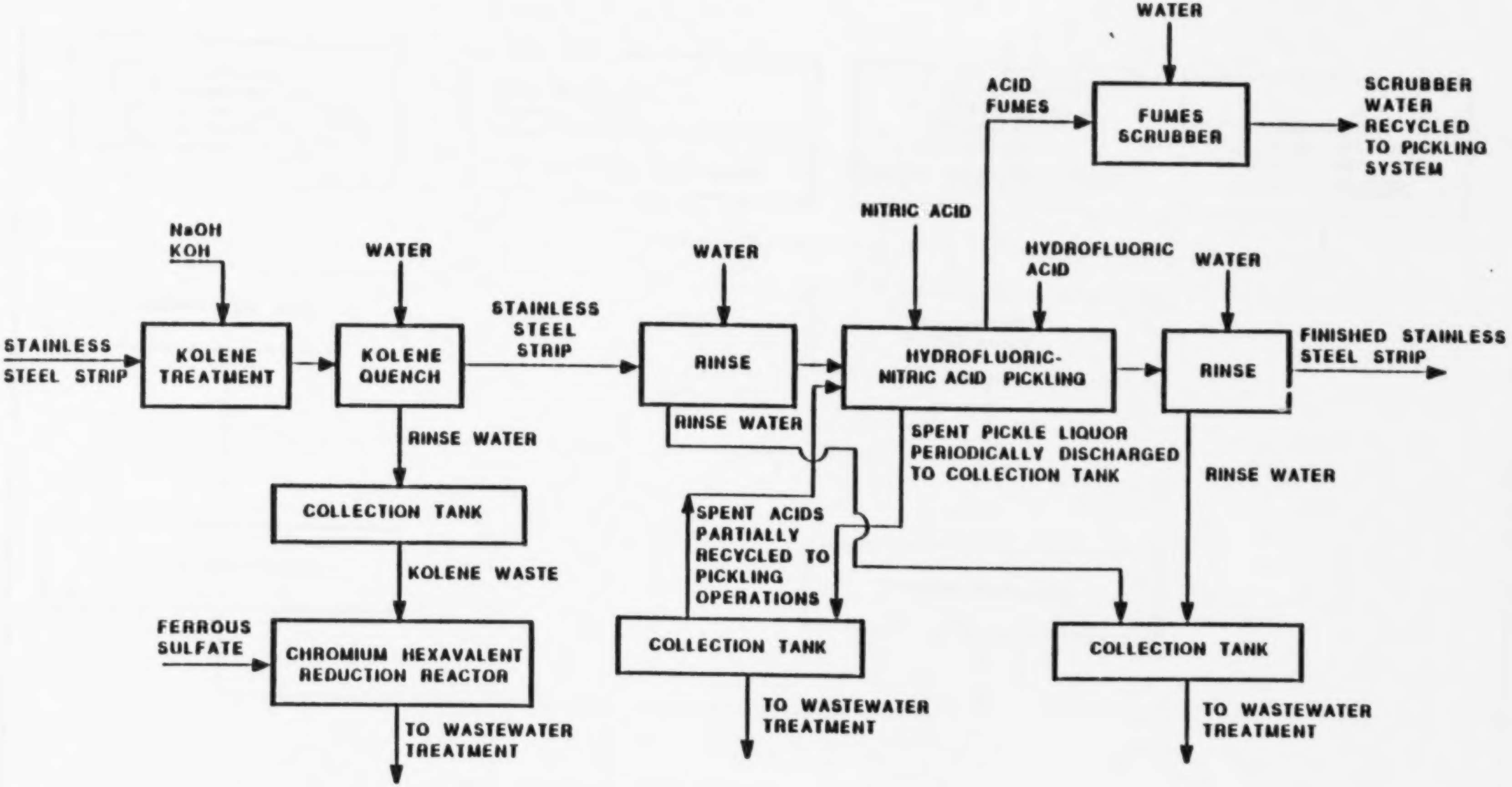


FIGURE 4. SIMPLIFIED SCHEMATIC OF EXISTING STAINLESS STEEL SURFACE TREATMENT AND PICKLING PROCESSES

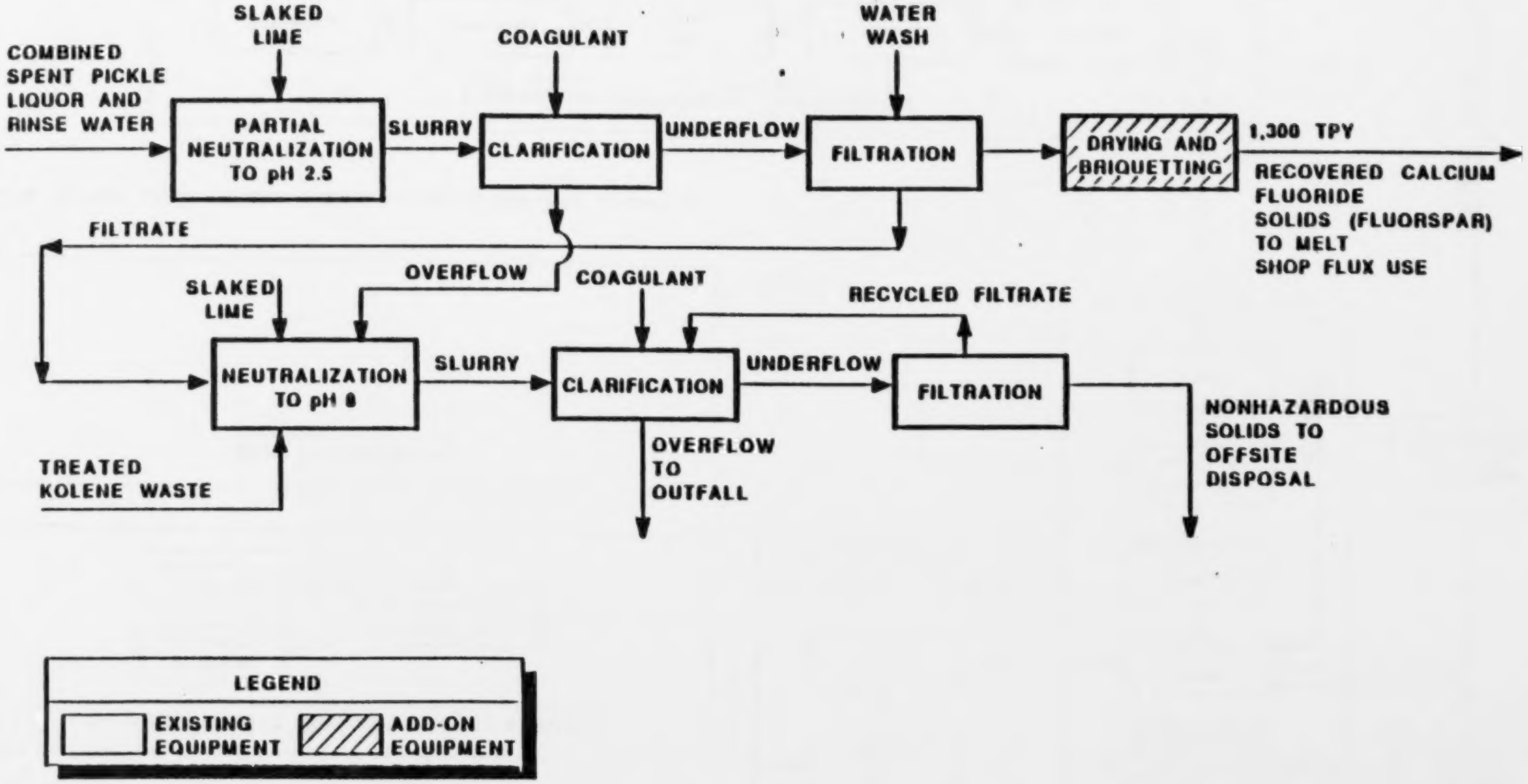
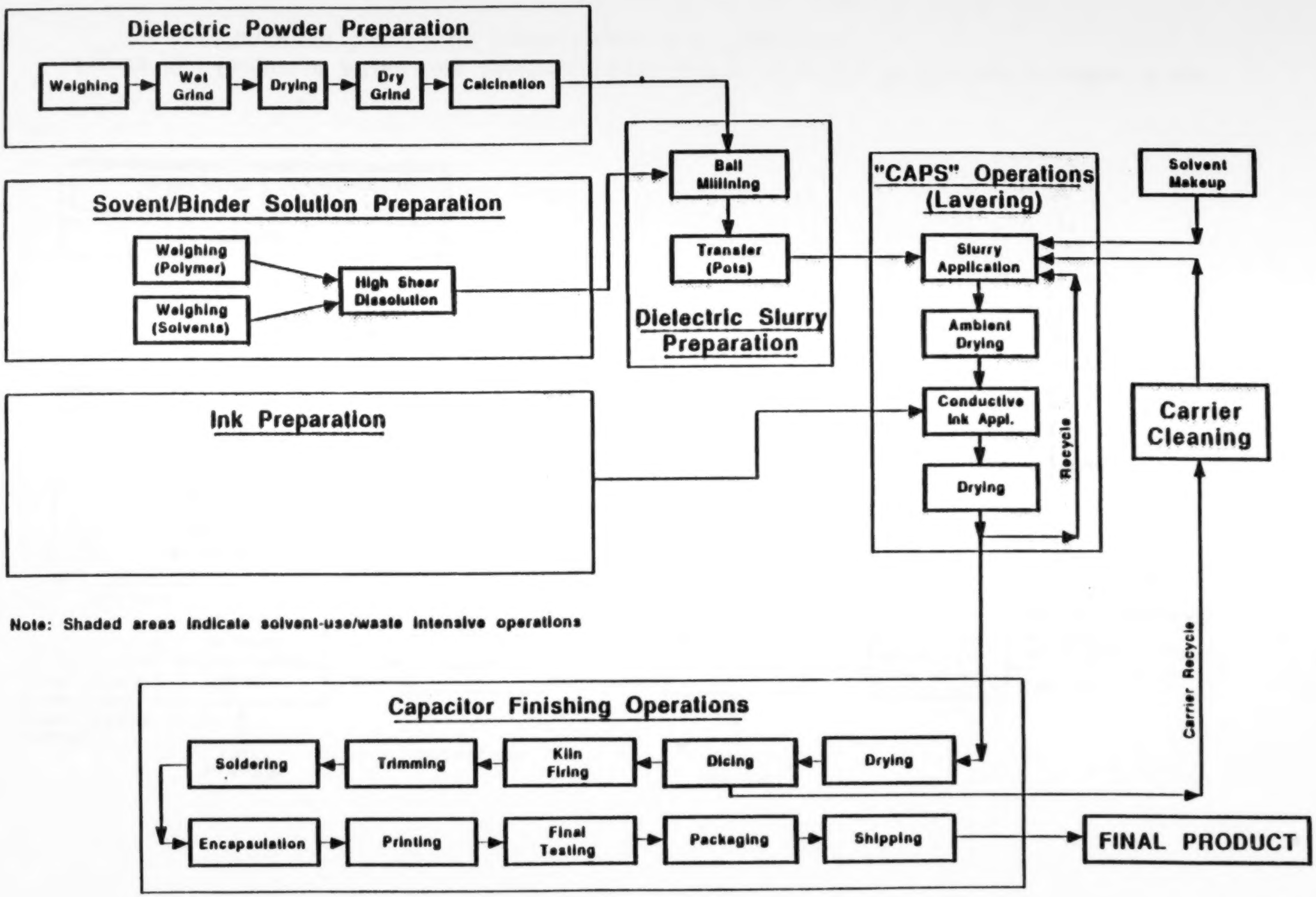


Figure 5. Proposed Alternative Treatment System For Recovery Of Calcium Fluoride From Combined Spent Acid Pickle Liquor And Rinsewater



Note: Shaded areas indicate solvent-use/waste intensive operations

FIGURE 6. SIMPLIFIED SCHEMATIC OF CERAMIC CAPACITOR MANUFACTURING PROCESS.

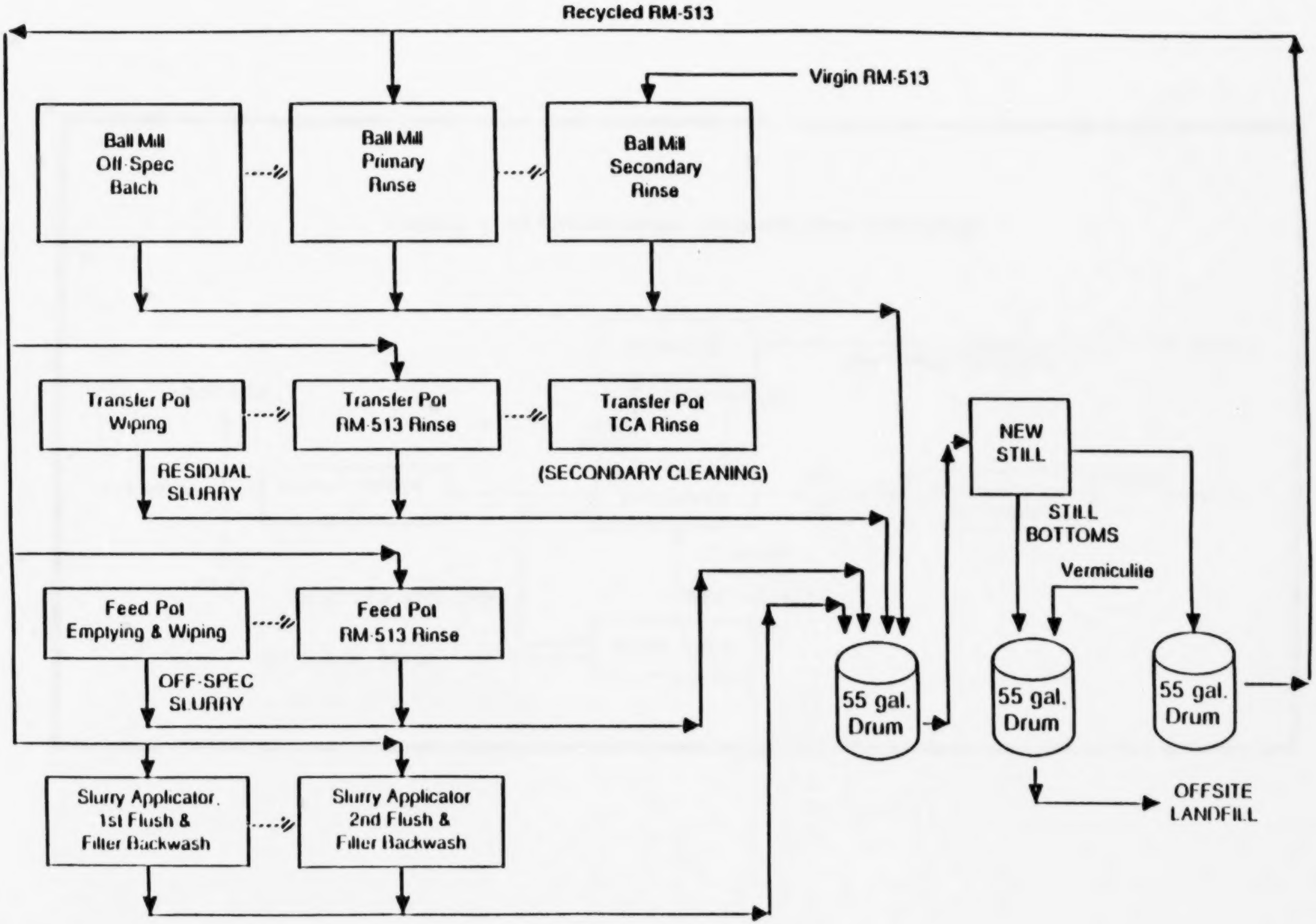


Figure 7. Proposed RM-513 Cleaning Solvent Recycle System.

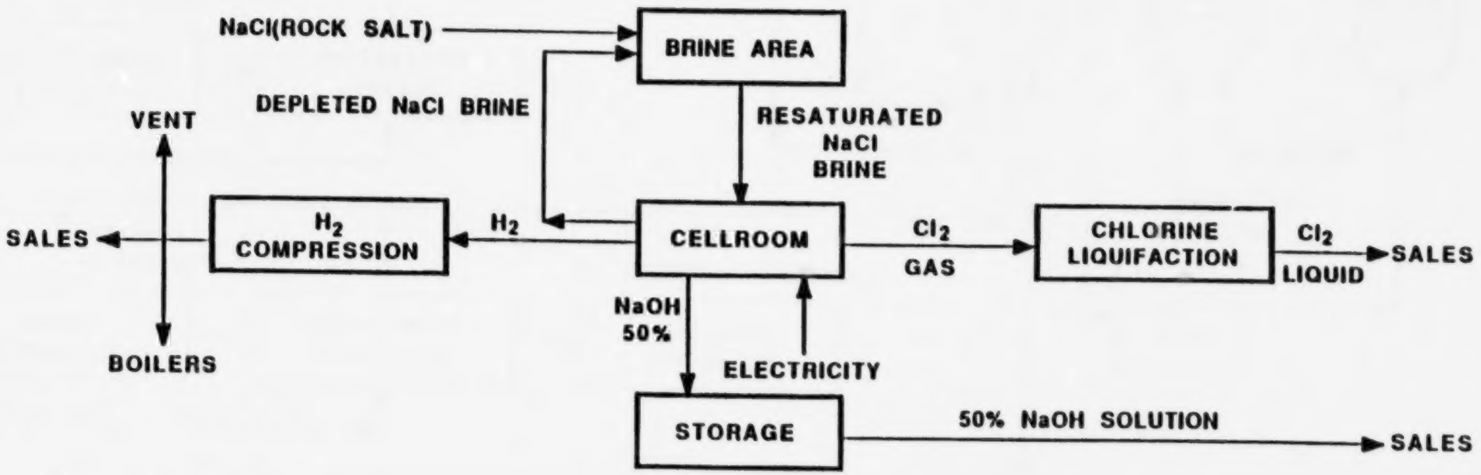


FIGURE 8. NaOH/CHLORINE PRODUCTION PROCESS

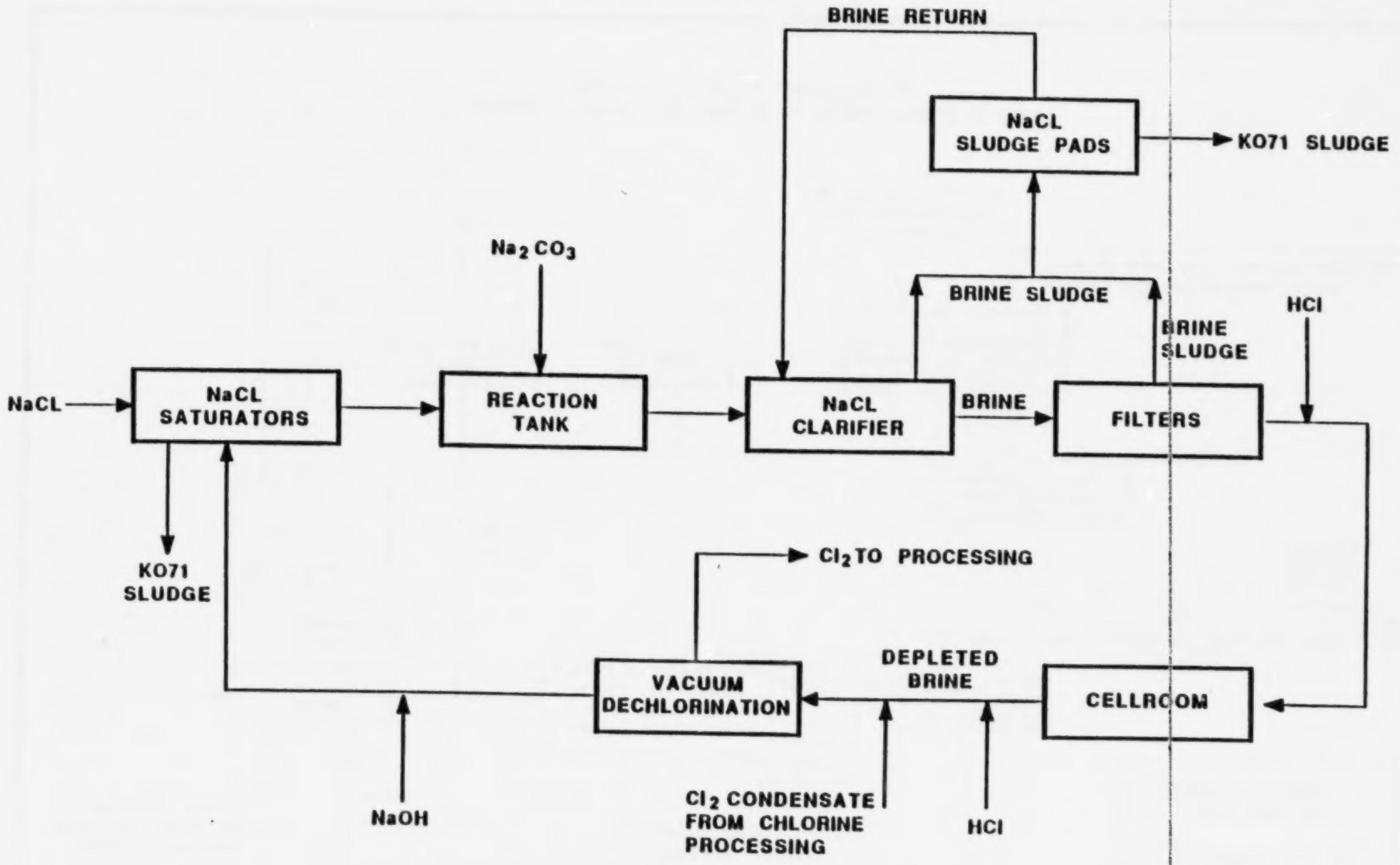


FIGURE 9. NaCl BRINE TREATMENT SYSTEM

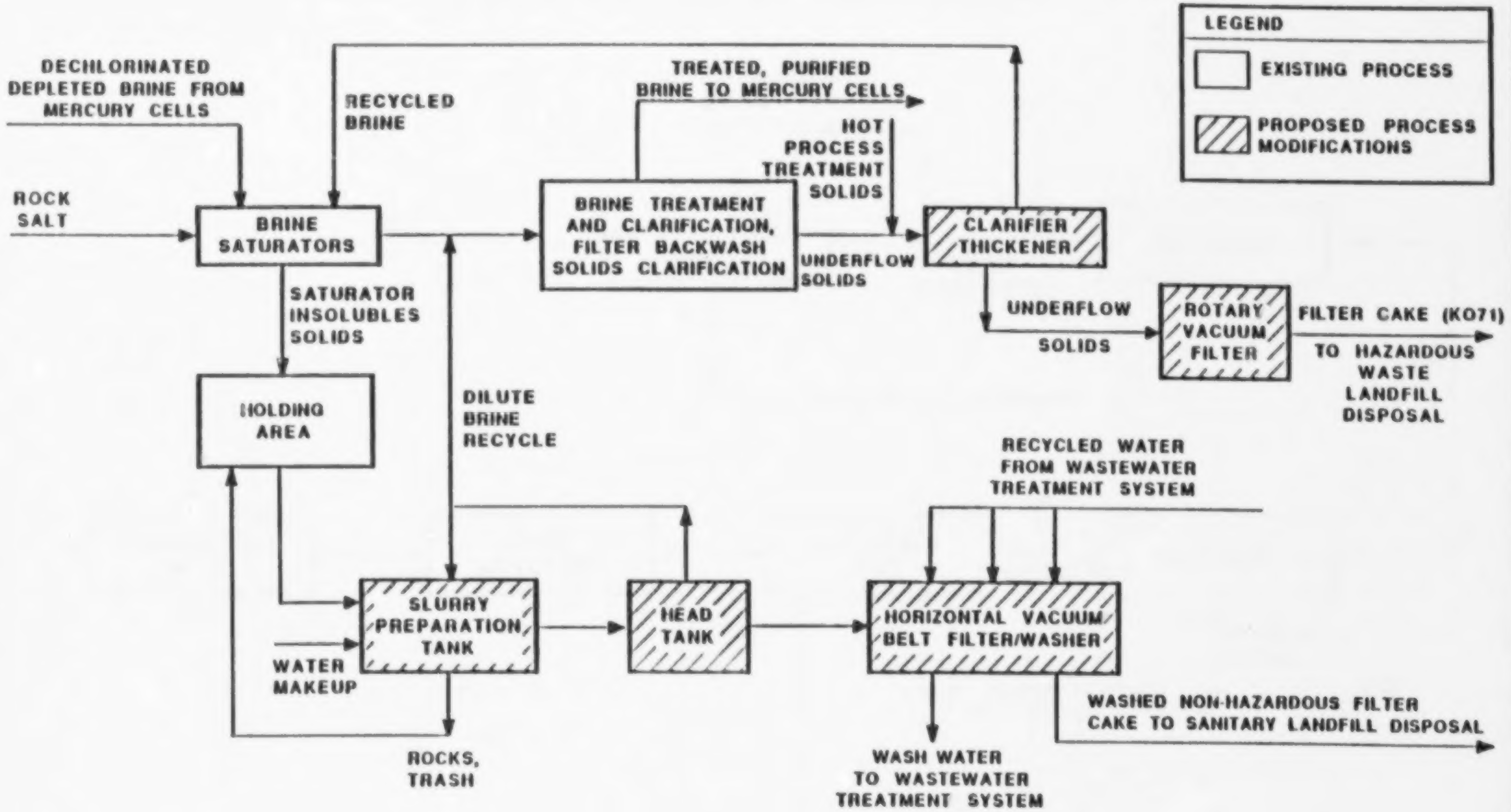

LEGEND
EXISTING PROCESS
PROPOSED PROCESS MODIFICATIONS
DECHLORINATED DEPLETED BRINE FROM MERCURY CELLS
ROCK SALT
RECYCLED BRINE
BRINE SATURATORS
SATURATOR INSOLUBLES SOLIDS
HOLDING AREA
DILUTE BRINE RECYCLE
BRINE TREATMENT AND CLARIFICATION, FILTER BACKWASH SOLIDS CLARIFICATION
TREATED, PURIFIED BRINE TO MERCURY CELLS
HOT PROCESS TREATMENT SOLIDS
UNDERFLOW SOLIDS
CLARIFIER THICKENER
UNDERFLOW
SOLIDS
ROTARY VACUUM FILTER
FILTER CAKE (K071)
TO HAZARDOUS WASTE LANDFILL DISPOSAL
SLURRY PREPARATION TANK
WATER MAKEUP
ROCKS, TRASH
HEAD TANK
RECYCLED WATER FROM WASTEWATER TREATMENT SYSTEM
HORIZONTAL VACUUM BELT FILTER/WASHER
WASH WATER TO WASTEWATER TREATMENT SYSTEM
WASHED NON-HAZARDOUS FILTER CAKE TO SANITARY LANDFILL DISPOSAL

FIGURE 10 PROPOSED WATER WASHING PROCESS FOR NaCl SATURATOR INSOLUBLES

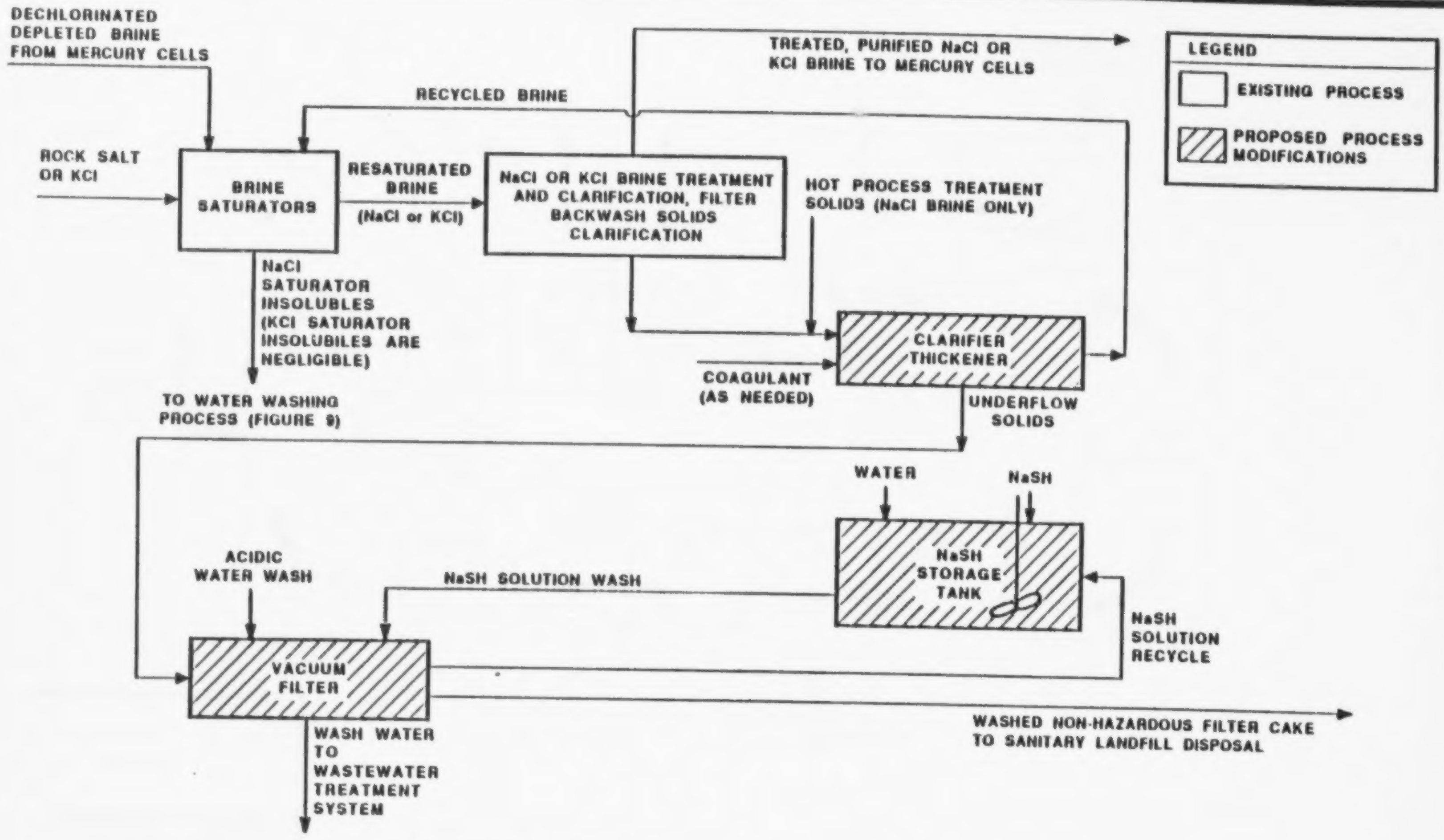

DECHLORINATED DEPLETED BRINE FROM MERCURY CELLS
ROCK SALT OR KCl
BRINE SATURATORS
RESATURATED BRINE
(NaCl or KCl)
NaCl OR KCl BRINE TREATMENT AND CLARIFICATION, FILTER BACKWASH SOLIDS CLARIFICATION
RECYCLED BRINE
TREATED, PURIFIED NaCl OR KCl BRINE TO MERCURY CELLS
LEGEND
EXISTING PROCESS
PROPOSED PROCESS MODIFICATIONS
NaCl SATURATOR INSOLUBLES (KCl SATURATOR INSOLUBILES ARE NEGLIGIBLE)
TO WATER WASHING PROCESS (FIGURE 9)
HOT PROCESS TREATMENT SOLIDS (NaCl BRINE ONLY)
COAGULANT (AS NEEDED)
CLARIFIER THICKENER
UNDERFLOW SOLIDS
WATER
NaSH
NaSH STORAGE TANK
NaSH SOLUTION WASH
NaSH SOLUTION RECYCLE
ACIDIC WATER WASH
VACUUM FILTER
WASH WATER TO WASTEWATER TREATMENT SYSTEM
WASHED NON-HAZARDOUS FILTER CAKE TO SANITARY LANDFILL DISPOSAL

FIGURE 11 PROPOSED SULFIDE PRECIPITATION OPTION FOR REMOVAL OF ENTRAINED MERCURY FROM THE K071 BRINE PURIFICATION WASTES

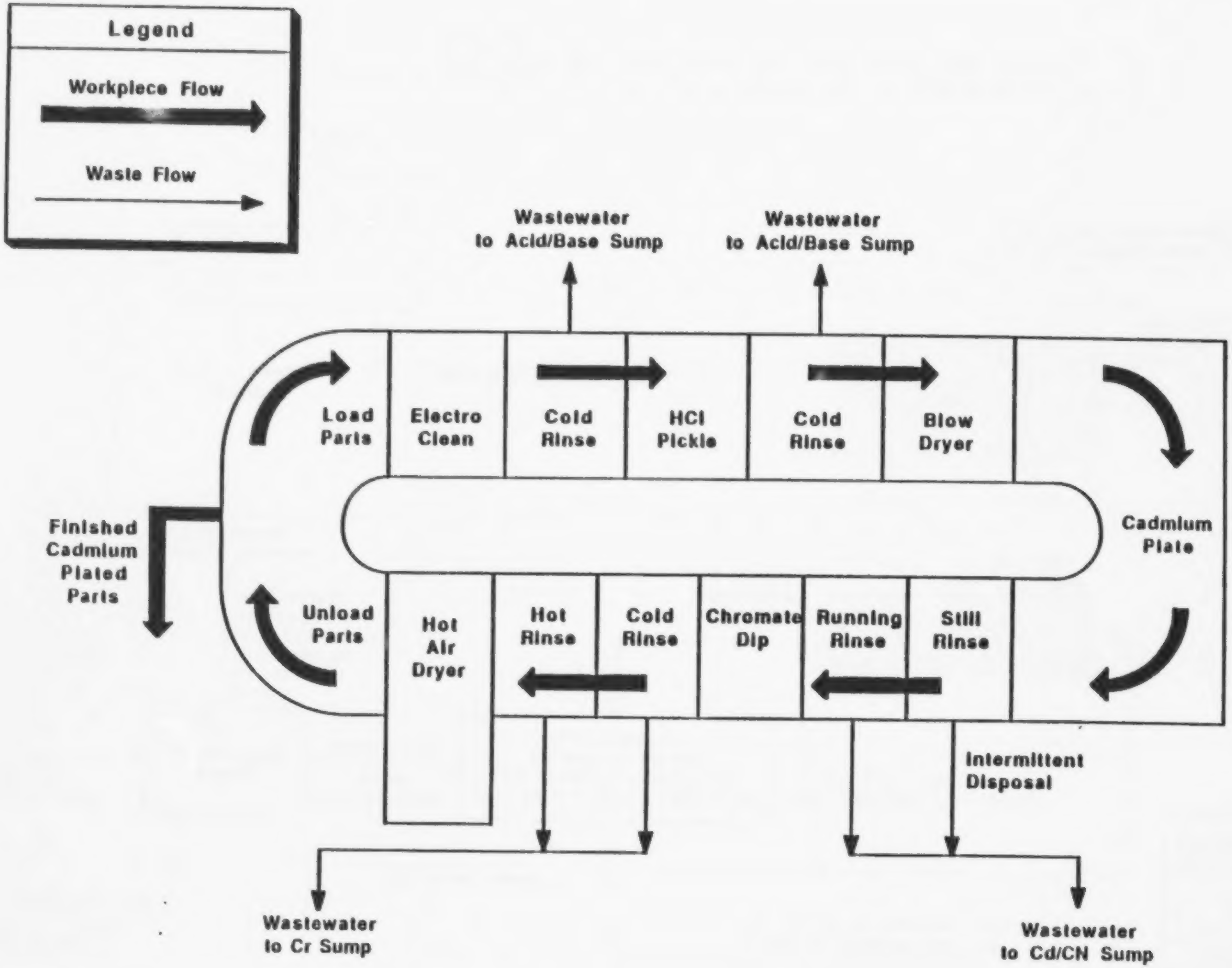


Figure 12. Simplified Schematic: Automatic Barrel Cadmium Plating Line

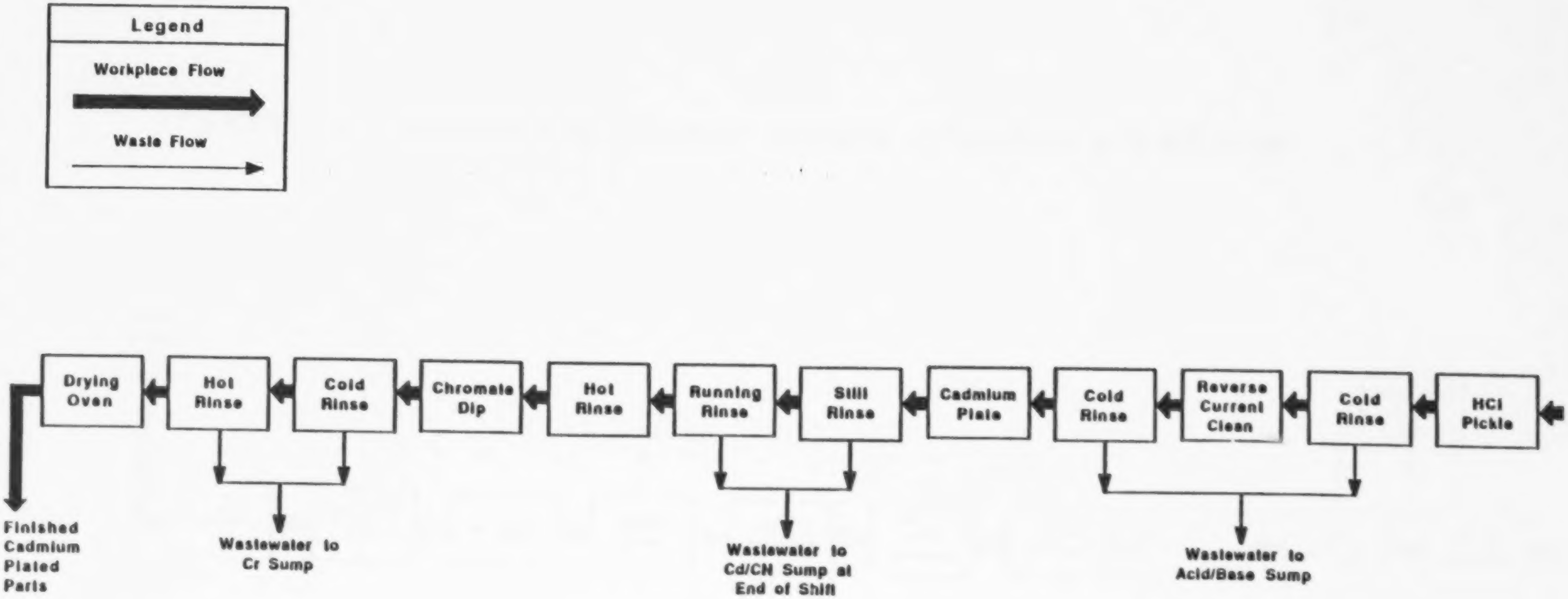


Figure 13. Simplified Schematic: Manual Cadmium Plating Line

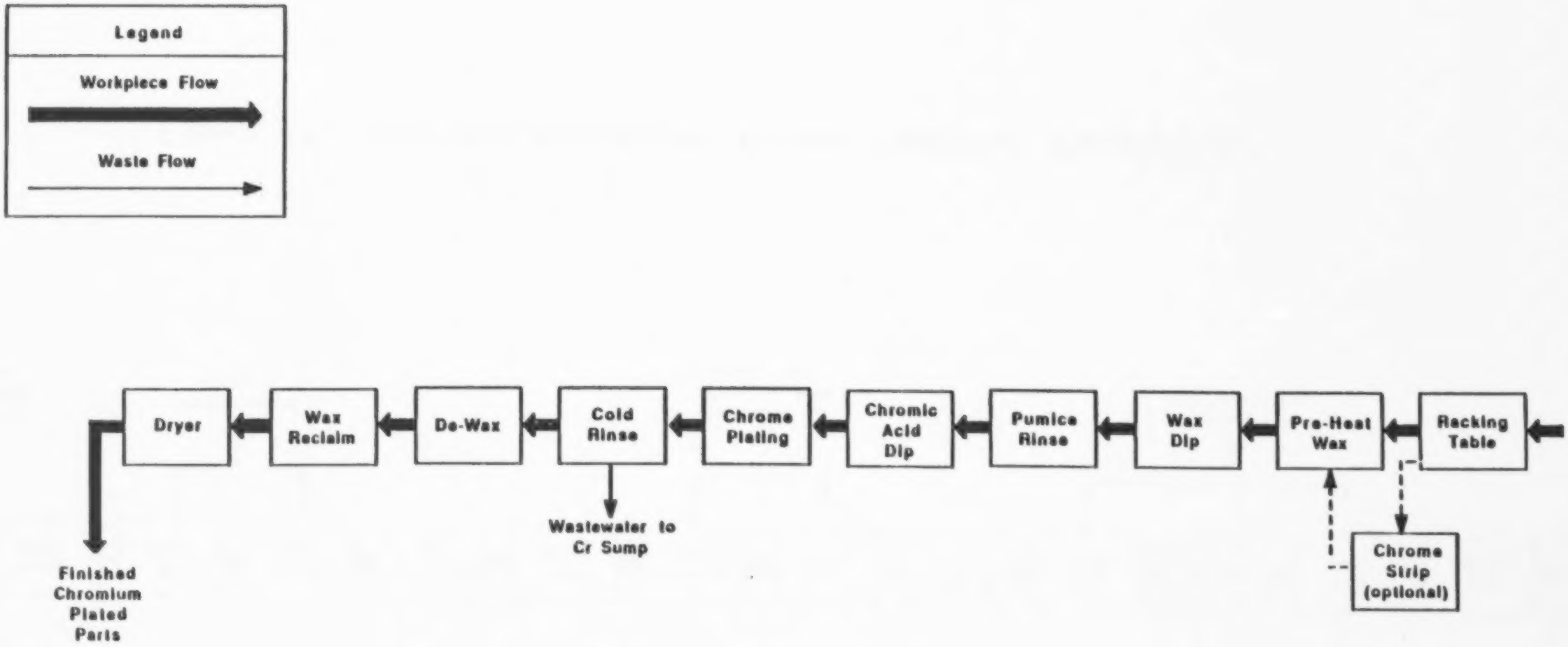


Figure 14. Simplified Schematic: Manual Chromium Plating Line

The Environmental Audit: Shield or Sword

Presented by
Edward A. Hogan, Esq.

Coauthored by
Lisa Murtha, Esq.
Porzio, Bromberg and Newman
Morristown, New Jersey

THE ENVIRONMENTAL AUDIT: SHIELD OR SWORD?*

EDWARD A. HOGAN** AND LISA MURTHA***

It has often been said that a little bit of knowledge is a bad thing. That is particularly and alarmingly true in the area of environmental audits. More important, therefore, than the question: "What can an environmental audit do for you?", is the question: "What can an environmental audit do to you?". The answer to that inquiry is "plenty" and unless a company undertaking such a task is prepared and committed to take both the good and the bad that may be generated by an environmental audit, it should neither commission nor perform one.

The well-established purpose of an environmental audit is to provide a concise, comprehensive evaluation of a company's actual and potential environmental liability and to measure the level of compliance with the myriad of local, state and federal regulations which govern the generation, treatment, storage, and disposal of hazardous substances and wastes. Financially, an environmental audit can reveal methods by which to streamline present practices and cut expenses and can provide a basis upon which to project the future costs of compliance. Environmentally, an audit can demonstrate whether a company is in full compliance

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** Principal and Chairman, Department of Environmental Law, Porzio, Bromberg & Newman, P.C., Morristown, New Jersey. B.S., St. Peter's College, M.F.S. Yale University School of Forestry and Environmental Studies, J.D., Georgetown University.

*** Associate, Department of Environmental Law, Porzio, Bromberg & Newman, P.C., Morristown, New Jersey. B.A., Summa Cum Laude, Caldwell College, J.D., Summa Cum Laude, Seton Hall University School of Law.

with the applicable regulations and, perhaps even more importantly, symbolize its interest in and commitment to maintaining high standards of environmental quality.

In addition to complementing a company's ongoing business, an environmental audit is an essential tool in the acquisition of new businesses. A competent review of a selling business' present and future environmental liability is of fundamental importance in the acquisition of that corporation and will significantly effect whether the sale occurs at all as well as the price.

With the ever growing complications of governmental regulation, the prohibitive costs of the generation,storage and disposal of hazardous substances, the threat of civil, monetary and criminal sanctions, and the potential for liability for personal injury and property damage, there can be no doubt that a complete and in-depth analysis of a company's environmental concerns is of the utmost importance.

Given the significant issues addressed by environmental audits it is no suprise that they now seem to be well-entrenched. First appearing in the mid-1970's when the Securities and Exchange Commission required three corporations to audit their environmental liabilities, over two-thirds of the larger companies in the basic manufacturing and process industries and over 50% of large companies in general, now perform environmental audits on a regular basis.

The legal consequences of an environmental audit are, however, grave and must be fully appreciated before such a process is initiated. Just as an audit may function as a shield protecting a business from potential liability, it may also act as a sword which can inflict serious, even fatal, damage if not properly sheathed. Accordingly, the issues which businesses conducting environmental audits must address early on are: "How best can that sword be sheathed?" and "What are the legal consequences of an environmental audit?"

Environmental audits can be harbingers of both good and bad news. The good news about environmental audits is that they can assure a company that it is in compliance with all pertinent regulations and statutes or, at least, compel swift compliance should it not have been achieved previously.

The bad news is that an environmental audit can generate information concerning the use and disposal of hazardous substances or wastes that, at worst, demonstrates a violation of the applicable laws and, at best, may trigger reporting responsibilities that will, in turn, invite governmental monitoring, intervention and oversight. It is imperative, therefore, that before undertaking an environmental audit, a corporation be prepared to confront the consequences of knowledge that may include:

1. The duty to report past and present violations.
2. The spectre of increased governmental inspection and oversight.

3. The imposition of civil or criminal penalties.

4. The necessity to perform remediation.

Conducting an environmental audit, therefore, is somewhat like eating of the forbidden fruit in the Garden of Eden. No matter how alluring it may be, it is an act that may banish a company from the paradise of self-satisfaction and environmental complacency. No company should initiate and no consultant should recommend an environmental audit unless it is clearly understood from the outset that information relevant to violations may be discovered and that information requiring governmental reporting or regulation may be unearthed.

Indeed, one of the most critical aspects of an environmental audit is that it can generate facts which will trigger a reporting responsibility on the part of the business conducting the audit. A number of state and federal environmental statutes impose a positive obligation to advise the responsible agencies of certain facts concerning not only present problems but environmental incidents which may have occurred in the past as well. Environmental audits may, therefore, directly lead to just that type of governmental entanglement that a business may be seeking to avoid through a thorough review of its environmental programs and systems.

For example, the New Jersey Spill Compensation and Control Act (N.J.S.A. 58:10-23.11 et seq.) specifically requires any person who has discharged hazardous substances or who is in any fashion responsible for the hazardous substances which may have been discharged, to notify the New Jersey Department of Environmental Protection (NJDEP). (N.J.S.A. 58:10-23.11e). The statute is applicable to discharges occurring both prior to and after April 1, 1977, the effective date of the Act. Accordingly, the obligation to report discharges applies not only to current or present discharges but also to the discovery of discharges which may have occurred in the past. The NJDEP has taken the position that the responsibility to report arises not only in regard to discharges of which an owner or an operator may be aware and which occurred either before or after the effective date of the statute but also in regard to discharges of which the owner or operator may not have been previously aware but which are later discovered. Discovery of contamination, therefore, which indicates that there must have been a past discharge, will trigger the reporting obligation. Similarly, reporting will be required in regard to property previously but not currently owned. Neither the Spill Act nor the associated regulations include any threshold, de minimus, quantities for purposes of reporting. The implementing regulations do, however, require reporting in regard to discharges of hazardous substances "in such quantities or concentrations as may be harmful or which poses a foreseeable risk of harm to public health or welfare, or to natural resources." N.J.A.C. 7:1E-2.1. The determination as to what amount would be harmful or would pose such a threat is left to the reporting party. Clearly, this standard is broad and the responsibility to report comprehensive. The facts determined through an environmental audit could, therefore, easily require a company to comply with the reporting requirements of the Spill Act.

Similarly, the Hazardous Substances Discharge-Reports and Notices Act, N.J.S.A. 13:1K-15 et seq., requires owners of industrial establishments or real property which was once a site of an industrial establishment to report known or suspected discharges of hazardous substances occurring either above or below ground. This act requires the owner to report such events not to the NJDEP, as in the Spill Act, but to the governing body of the municipality in which the industrial establishment or property is located and to the local health department. These local agencies, in turn, are responsible for advising the NJDEP. An industrial establishment is any business which handles hazardous substances and has an SIC number within groups 22 through 39, 46 through 49, 51, 55, 75 or 76. Hazardous discharges are defined as discharges reportable to NJDEP pursuant to the Spill Act.

A number of additional state and federal statutes, including the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (42 USCA §9603(a)) and others not listed herein, contain similar reporting requirements that may be activated by the information developed through an environmental audit. Environmental audits should, therefore, be undertaken only with a complete understanding of these possible responsibilities.

In addition to revealing facts requiring reporting, audits can develop facts which may not require notification to governmental agencies but which are, nonetheless, alarming or disturbing. Moreover, ignoring the bad news of an environmental audit can lead to violation notices, fines, criminal sanctions, private liability, and a severely damaged public reputation. Without question the failure to address known problems is clearly more damning than the failure to discover those problems in the first instance. Knowing violations of environmental regulations will, in some instances, absolutely assure the imposition of criminal sanctions upon responsible company employees. [Under RCRA, for example, penalties starting at $50,000 per day of violation plus a term of imprisonment may be imposed for knowingly violating the provisions of that and other statutes. See 42 U.S.C. §6928(d) and (e). Criminal penalties may also be imposed under the federal Clean Air Act (42 U.S.C. §7413(c)), the federal Clean Water Act (33 U.S.C. §1319(c)); the state Air Pollution Emergency Control Act (N.J.S.A. 26:2C-33) and the state Water Pollution Control Act (N.J.S.A. 58:10A-10).] In short, a business should not perform or initiate an environmental audit unless it is committed to confronting the responsibility conferred by knowledge.

Similarly, environmental audits can easily be transformed into instruments of destruction if they become available to the general public or if they are discovered by adversaries during the course of litigation. By performing an audit a corporation may, in fact, be preparing the very record needed to destroy it in litigation or enforcement actions. In short, from a regulatory point of view, an environmental audit can provide the United States Environmental Protection Agency (EPA) with a ready-made basis for instituting an enforcement action. Public disclosure of environmental audits can destroy a company's previously good public reputation, can invite the institution of citizen's suits provided for under several of the federal environmental statutes, and can clearly place a company in a disadvantageous position in on-going litigation. In each of these instances a business' own environmmental audit can, ironically enough, be used against it. From a legal perspective, however, there are means by which to insulate an environmental audit, at least to a certain extent, from the ramifications of public exposure and from the effects of release to adversaries in litigation.

Although a company may internally limit the distribution or publication of an environmental audit and intend to preserve its confidentiality, it may nevertheless be disclosed either through the request of the EPA for reports or information or through the request of adversaries in litigation by use of the rules of pre-trial discovery. Both the broad administative enforcement powers of the EPA and the liberally construed rules of discovery are sufficiently comprehensive to compel the production of audits. Companies may, therefore, be vulnerable to the disclosure of what they meant to be confidential and private internal documents.

A number of so called privileges, which have arisen in the course of general litigation, may be applied to environmental audits to protect them against public dissemination. More specifically, there are three privileges that may be invoked:

1. The lawyer-client privilege.
2. The work-product rule.
3. The privilege of self-evaluative analysis.

Preliminarily, it is essential to the protection of an environmental audit to involve legal counsel as soon as possible in all aspects of the audit. Because the assurance of the confidentialty of an environmental audit is as critical as the audit itself, the participation of counsel is a measure of caution that should be assured early on. Without the association of counsel, the lawyer-client privilege and the work-product rule will not apply at all. Similarly, the involvement of an attorney at the outset will ensure that the environmental audit and the audit process are structured so as to assure the maximum degree of insulation. The necessity for legal advice and supervision in the environmental audit is a factor which must, therefore, be considered at the time that the company is first considering the performance of an audit. Legal participation will demand a commitment of the time of in-house counsel or, alternatively, the commitment of resources to the cost of retaining outside counsel. In view of the ramifications of public disclosure of such audits it is, however, a cost well worth incurring.

Although industry, long sensitive to the need for the non-disclosure of environmental audits, has consistently urged the EPA to adopt rules or policies assuring the confidentiality of such reports, the Agency has declined to do so to date. Indeed, it has been suggested that in order to encourage environmental audits the EPA should agree not to seek the production of such reports in enforcement actions thereby assuring some degree of protection. Given the agency's ability to compel the collection and production of such materials independent of the audit, such protections would have no effect on its ability to enforce compliance. Conversely, a policy insulating internal audits would encourage voluntary, self-policing by industry. Therefore, although at some point the EPA may accede to the wishes of business to grant some degree of protection, the only privileges presently available are those generally developed in the context of litigation.

THE LAWYER-CLIENT PRIVILEGE

The laywer-client privilege, codified in New Jersey as Rule 26 of the New Jersey Rules of Evidence, provides that:

> ... communications between a lawyer and his client in the course of that relationship and in professional confidence are privileged and a client has a privilege (a) to refuse to disclose any such communication, and (b) to prevent his lawyer from disclosing it, and (c) to prevent any other witness from disclosing such communication if it comes to the knowledge of such witness (i) in the course of its transmittal between the client and the lawyer, or (ii) in a manner not reasonably to be anticipated or (iii) as a result of a breach of the lawyer-client relationship or (iv) in the course of a recognized confidential and privileged communication between such client and witness.

This rule generally protects discussions, communications, and correspondence between counsel and client providing they occur in the context of a professional relationship. In order to invoke this privilege it must have been the intent of the parties to the communication that it be kept confidential. The circulation of the audit or its preliminary drafts should, therefore, be limited to only the lawyer, the consultants engaged by the lawyer, and those in the corporation who need to know the results of the audit.

There are, of course, exceptions to the privilege. These, too, are set forth in the rule. The only exception relevant to this particular area provides that the privilege shall not extend to a communcation occurring in the course of legal services sought or obtained in aid of the commission of a crime or a fraud. To the extent that failure to comply with or violation of the federal or state environmental statutes constitutes a criminal offense this exception may apply to communications between a client and a lawyer which relate to the perpetuation or commitment of such activity. As such, these communications are not within the shield or the protection and may be revealed. Indeed, in some instances they must be reported by the attorney. This is a significant caveat that should be clearly understood by the client from the outset. A lawyer cannot be used to protect communications regarding the commission of criminal activity. This exception refers, however, only to communications in aid of the commission of a criminal act. It does not exclude from protection discussions concerning completed or antecedent criminal activity. Matthews v. Hoagland, 48 N.J. Eq. 455 (Ch. 1891).

"Client", in the term lawyer-client privilege, is defined to include corporations that consult a lawyer for the purpose of retaining the lawyer or securing legal services or advice from him in his professional capacity. Early case law limited the extent of the protection in the corporate context to communications between the lawyer and only those corporate employees responsible for directing a corporation's action in response to legal advice, the so-called "control group". In Upjohn Co. v. United States, 449 U.S 383, 103 S.Ct. 677, 66 L.Ed.2d 584 (1981), however, the United States Supreme Court broadened the protection to include communications between a lawyer and any employee providing the disclosure concerned matters within the employee's scope of corporate duties and providing that the communication was made for the purpose of enabling the lawyer to provide legal advice to the corporate client. See also SICPA North America v. Donaldson Enterprises, Inc., 179 N.J. Super 56 (Law Div. 1981), United Jersey Bank v. Wolosoff, 196 N.J. Super 553 (App. Div. 1984). Therefore, a communication between an employee and an attorney retained for the purpose of providing counsel to the corporation will be protected from disclosure, providing the communication pertains to information within the employee's scope of employment and relates to the legal matter for which the attorney has been engaged.

The Courts have created a distinction between "communications" which may be protected by the privilege and the "facts" communicated which may not be privileged. A communication involves a conversation between the employee and the lawyer. The privilege provides that the employee or the lawyer may not be questioned as to what was said during that conversation. A "fact", however, which may be within a client's knowledge and which may have been communicated during the course of the conversation with the attorney is not protected even though relayed to a lawyer as a basis for providing legal advice. UpJohn Co. v. United States, 449 U.S. 383, 101 S.Ct. 677, 66 L.Ed.2d 584 (1981), Philadelphia v. Westinghouse Electric Corp., 205 F.Supp. 830 (E.D. Pa. 1962).

Information, therefore, concerning the facts of company's environmental compliance or noncompliance (i.e. existence of hazardous substances or wastes, manners of disposal, quantities or types of discharges, spills, etc.) are not protected by the laywer-client privilege, even though provided to an attorney in a course of preparing an environmental audit. Anyone may freely inquire into those facts. What would be protected, however, is any discussion the attorney and the client may have had concerning the facts and, even more importantly, the attorney's advice in response to those facts. Accordingly, any plan, response or advice which an attorney may formulate in an environmental audit as well as the attorney's assessment of liability will all be protected by the lawyer-client privilege although the facts underlying the advice will not be shielded.

An important caveat in invoking the laywer-client privilege is that during the course of the professional relationship the attorney must be acting in his role as an attorney in order to claim the privilege. The communication must be made for the purpose of obtaining legal advice. The privilege is limited to communications made to an attorney acting in his or her professional capacity. If, then, the lawyer is being used merely to gather information and compile it into the report, the lawyer is, in fact, performing a task that could be performed by a non-lawyer. As such, communications made to the lawyer in that context are not protected. See Metalsalts Corp. v. Weiss, 76

N.J. Super. 291 (Ch. Div. 1962), United Jersey Bank v. Wolosoff, 196 N.J. Super. 553 (App. Div. 1984), L.J. v. J.B., 150 N.J. Super. 373 (App. Div. 1977). Only if the attorney is acting in a professional capacity either in preparing for litigation or in the process of rendering legal advice is the communication within the ambit of the privilege. In preparing environmental audits, then, it is imperative to draft the aid of the attorney not merely as a clearing-house to gather information and data but additionally to solicit legal advice in regard to the environmental issues addressed in the audit. This should be made crystal clear in any correspondence retaining counsel in relation to the environmental audit.

Similarly, the audit itself should be structured as a legal opinion rendered in response to the information gathered in the course of the audit.

The use of in-house counsel presents special problems in this regard as it may be difficult in some instances to separate purely legal tasks from simply information-gathering or ministerial tasks. Again, in enlisting the aid of in-house counsel it is important, for the purposes of maintaining confidentiality, to limit their responsibility to the rendering of legal advice to protect the audit.

Simply compiling a report without the participation of counsel but later including it into the corporation's legal file or directing it to the legal department would be an inadequate basis upon which to claim the protection offered by this privilege. Wylie v. Mills, 195 N.J. Super. 332 (Law Div. 1984).

The six simple rules, then, of preserving the shield of this protection include:

1. Involve legal counsel at the beginning of the process.
2. Clearly designate counsel's role in the process as providing legal advice and guidance.
3. Limit the participants to communications to the lawyer and the employees of the client with relevant knowledge or a need to know.
4. Incorporate the attorney's advice, guidance and opinion in the audit and label it as such.
5. Memoralize the intent that communications regarding the audit are to be kept confidential.
6. Confirm and reconfirm the attorneys' role in all correspondence.

In sum, in order to secure the shield offered by the lawyer-client privilege for an environmental audit it is necessary to involve counsel in the process of information gathering and evaluation and, more importantly, in that phase of the audit relative to a company's response and reaction. Mere token association of legal counsel will severely threaten the applicability of the privilege.

WORK-PRODUCT RULE

A related privilege, the work-product rule, may also be used under certain circumstances to protect at least part of the environmental audit. This privilege shields from production or release documents prepared in anticipation of or in preparation for litigation. If an environmental audit, then, is prepared in the course of an on-going lawsuit or in anticipation of a lawsuit for the purpose of evaluating a company's past, present and future environmental liability, a claim may be made that it is shielded from public scrutiny by this privilege. More often, however, an audit is prepared as a matter of good management. As such, it cannot be said to have been prepared in anticipation of litigation. To help build a record in this regard, the company should document, either in the letter retaining counsel concerning the performance of the audit or in the audit itself, that it anticipates an enforcement action or litigation and why. An unsubstantiated recitation that litigation may occur will be inadequate to trigger the work-product rule. There must be a good-faith expectation of such action.

A simple method of at least providing a basis for the invocation of this rule is to mark all correspondence between attorney and client as "Privileged and Confidential." While this designation will not, of course, assure confidentiality it will signal the intention of the parties should the issue later arise.

The work-product rule, set forth in Rule 4:10-2(c) of the Rules Governing the Courts of the State of New Jersey, provides that the information in the audit may be released if the party seeking disclosure can demonstrate that it has a "substantial" need for the materials in question and that it is unable, without undue hardship, to obtain a substantial equivalent of these materials by other means. See also Hickman v. Taylor, 329 U.S. 495, 67 S.Ct. 385, 91 L.Ed. 451 (1947). Even where an opponent can make such a showing, the courts are directed to protect against the disclosure of the mental impressions, conclusions, opinions or legal theories of the attorney concerning the litigation. At least that portion of the environmental audit, then, which includes counsel's evaluation of a company's present environmental systems, its vulnerability to suit, its chances of success should suit actually be instituted, the formulation of environmental strategies and similar opinions could be brought within the protection of the work-product rule even if the rest of the investigation in the audit could be revealed. For that reason, those portions of the audit containing such opinions should be clearly designated as such. They may, then, be more easily excised should the audit have to be disclosed.

In terms of damage control, it is clear that the greater potential for problems rests not with the discovery of the facts unearthed by the audit but with the discovery of a company's response or non-response to these problems. For example, a company's failure to comply with its own in-house control systems, its failure to design response plans, or its policy in regard to continuing problems can severly cripple its ability to enter into settlements with the government or private litigants. An audit, by bringing the facts of violations into focus, can transform a business into a knowing violator that can, in turn, justify criminal sanctions. If an important aspect of environmental audits is to solve problems, a company must, then, be free to insure the confidentiality of its response to problems. The protection afforded by the work-product rule shields the response plan and alternatives suggested by legal counsel. This protection, then, while not all-encompassing, protects the most sensitive portions of the audit.

The courts which have considered the protection afforded by the work-product rule have held that an attorney's notes of interviews with employees or oral statements by employees are protected as opinion work product even though an employee's own written account may not be so protected. Upjohn Co. v. United States, 449 U.S. 383, 501 S.Ct. 677, 66 L.Ed. 2d 584 (1981). Therefore, the guarantee of protection is enhanced by permitting an attorney to gather the necessary information for the audit himself and to record it in his or her own handwriting.

To claim the protections afforded by the work-product rule a company should:

1. perform environmental audits anticipating suit either by the government in enforcement actions or private citizens in citizen suits,

2. designate sensitive documents as "Privileged and Confidential",

3. avoid the generation of reports, writings, memorandum, and

4. permit counsel to gather and memorialize the necessary information.

PRIVILEGE OF SELF-EVALUATIVE ANALYSIS

The final privilege which may be invoked to shield an environmental audit against public disclosure, the privilege of self-evaluative analysis, is a less well established but potentially useful tool of confidentialty. This privilege seeks to protect reports, documents, studies, etc. generated in the process of studying a particular problem, issue or accident. The policy behind according confidentialty to such documents is the interest in encouraging business to review and analyze situations so as to avoid similar future accidents and incidents. By freely compelling the production of such studies, it is feared that candid, thorough review will be stifled. Because this privilege, also referred to as the privilege of self-examination or self-critical analysis, has not yet won wide acceptance in New Jersey, the protections it may afford are clearly less certain than those provided by the lawyer-client privilege and the work-product rule.

In order for this protection to apply, the business must demonstrate that:

1. the audit process is a self-evaluative process,

2. there is a strong public interest in environmental auditing, and

3. there is a likelihood that environmentally beneficial auditing would be curtailed unless confidentiality was assured.

The privilege of self-critical analysis is said to prevent the disclosure of "confidential, critical, evaluative and/or deliberative material whenever the public interest in confidence outweighs an individual's need for full discovery." Wylie v. Mills, 195 N.J.Super 332, 338 (Law Div. 1984). It will protect criticisms and evaluations deemed to be essential in recognizing the cause of past problems and the elimination of future problems. The courts in New Jersey have recognized that:

> Valuable criticism can neither be sought nor generated in the shadow of potential or even possible public disclosure. It is not realistic to expect candid expressions of opinion or suggestions as to future policy or procedures in an air of apprehension that such statements will be used against a colleague or employer in a subsequent litigated matter.
>
> The purpose of an investigation intended to seek criticism, opinion, or suggestion and form the basis of then existing policy or procedure is self-improvement. The value of the investigation is questionable if the input is not reliable. It is clear that the reliability of the input in the situation varies inversely with the risk of the disclosure or the input or results of criticism. [Wylie v. Mills, 195 N.J. Super. 332, 340 (Law Div. 1984)].

This privilege is specifically applicable to a corporation's internal evaluative reports. Environmental audits would clearly appear to fall within this category of documents.

Like the lawyer-client privilege, however, the privilege of self-evaluative analysis, when applied, has not been extended to factual information contained in such reports. Only the "evaluative" portions of the reports have been deemed to be protected.

As in the work-product rule, courts in this context will weigh the need for the information against the interest in preserving its confidentialty. If the information in question is unavailable from other sources more serious consideration will be given to compelling its production.

Unlike the other privileges, the applicability of this privilege is limited. It has generally been honored only in the context of discovery in private actions. It has not been held to protect against disclosure in governmental enforcement actions. Therefore, it may not protect an audit from disclosure to a governmental agency.

CONCLUSION

In conclusion, while environmental audits can help a company to assess potential liability, predict the cost of doing business, assure compliance, and analyze what must be done in the future, they can, at the same time, clear a path of destruction unless properly protected and insulated. The legal consequences of an environmental audit are significant. At the outset, it is critical to understand that the information and facts generated by an environmental audit may create a responsibility to respond

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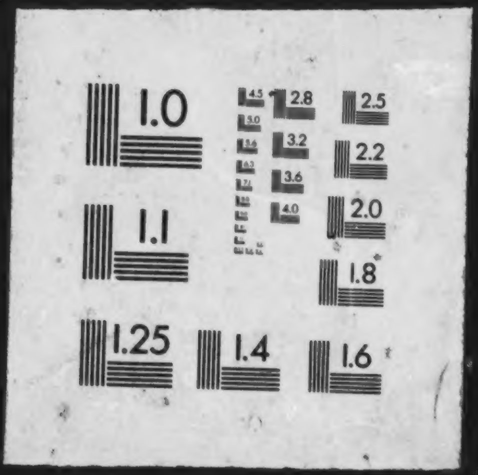

on the part of the corporation. The results of the audit may trigger a reporting duty of which the corporation was previously unaware. They may similarly reveal situations requiring the outlay of considerable time and capital to correct and assure compliance. Failure to address problems revealed by an environmental audit will surely compound the difficulties posed by the problems themselves and increase the likelihood of criminal sanctions.

Unless properly protected, an environmental audit can provide ammunition for adversaries in citizen's suits. If publicly disseminated, environmental audits can also destroy a company's previously good reputation in the community. It is, therefore, imperative to understand the privileges which may protect an environmental audit and to structure the audit so as to assure to the company the greatest protection possible. The lawyer-client privilege, the work-product rule and the privilege of self-evaluative analysis can all shield, at least in part, the environmental audit and help to preserve it as a helpful rather than a harmful management tool.

Waste Minimization: An Update

Presented by
Harry Freeman
Research Program Manager
Hazardous Waste Engineering Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, Ohio

WASTE MINIMIZATION: AN UPDATE

Harry Freeman
U.S. Environmental Protection Agency
Hazardous Waste Engineering Research Laboratory
Cincinnati, OH

Background

There is a national policy in the United States to eliminate the generation of hazardous waste. The U.S. Congress stated in the Hazardous and Solid Waste Amendments of 1984 to the Resource Conservation and Recovery Act of 1976:

> The Congress hereby declares it to be the national policy of the United States that, wherever feasible, the generation of hazardous waste is to be reduced or eliminated as expeditiously as possible. Waste that is nevertheless generated should be treated, stored or disposed of so as to minimize the present and future threat to human health and the environment.

Reflecting the intent of this policy, there have been adopted by the EPA and other public agencies similar variations of the hierarchy shown below as a guide for hazardous waste management options:

1. Source reduction: reduce the amount of waste at the source through changes in industrial processes;
2. Waste separation and concentration: isolate hazardous materials from mixtures in which they occur;
3. Waste exchange: transfer wastes through clearinghouses so that they can be recycled in industrial processes;
4. Energy/material recovery: reuse and recycle wastes for the original or some other purpose, such as for materials recovery or energy production;
5. Incineration/treatment: destroy, detoxify, and neutralize wastes into less harmful substances; and
6. Secure land disposal: deposit wastes on land using volume reduction, encapsulation, leachate containment, monitoring, and controlled air and surface/subsurface water releases.*

The term "waste minimization" has been defined differently by different organizations. The USEPA, in its October 1986 Report to Congress on the minimization of hazardous waste, defined waste minimization as:

> The reduction, to the extent feasible, of hazardous waste that is generated or subsequently treated, stored, or disposed of. It includes any source reduction or recycling activity undertaken by a generator that results in either: (1) the reduction of total volume or quantity of hazardous waste or (2) the reduction of toxicity of hazardous waste, or both, so long as the reduction is consistent with the goal of minimizing present and future threats to human health and the environment.

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*This six-point hierarchy is contained in 41 FR 35050, August 18, 1976.

In addition to the EPA Report to Congress, other studies by the Office of Technology Assessment, the EPA's Science Advisory Board, the National Research Council, and others have shown general agreement that an EPA program to encourage industry to accelerate its efforts to reduce the generation of wastes should be an important Agency objective. EPA's efforts should support and catalyze both the development and industry acceptance of industrial manufacturing and production techniques and recycling methods (both in-process and otherwise) that will produce less waste and/or less-hazardous waste for treatment and disposal.

At least 10 of the states have initiated rather significant programs to encourage industries within their boundaries to reduce waste generation. Most of the ideas contained in this proposed Agency strategy are based on successful programs that have been undertaken by the various states. Consequently, the programs and experiences of these states will be utilized by the Agency in structuring the federal programs proposed in this document. The success of this strategy will be based to a great extent on the success of the Agency in incorporating the states as partners in the effort.

Although it is really quite difficult to know with certainty how much industrial waste could be eliminated through stepped-up waste minimization programs, it is strongly suspected that the amounts are very significant. The EPA Report to Congress contained data that suggested that, in general, industry could still reduce their hazardous waste streams by 20 to 30 percent. The EPA and OTA policy studies include many examples of successful waste minimization activities. The Massachusetts League of Women Voters has compiled reports regarding 20 to 30 of the major companies in the country that show that waste minimization on the order of 30 to 50 percent is not at all out of the ordinary when waste minimization has been actively supported by a company's management. The OTA has suggested that a goal of 10 percent waste reduction annually for the next five years for the country as a whole is not beyond achievement.

The Current EPA Waste Minimization Program

Office of Solid Waste. For the past two years, the Office of Solid Waste (OSW) has been actively involved in the area of waste minimization. In October of 1986, the EPA submitted the Report to Congress on the minimization of hazardous waste. The report was the culmination of an extensive study conducted by OSW on source reduction and recycling techniques, the two primary elements of waste minimization. The goal of this study was to profile current waste minimization practices by the industrial sector and make estimates on current and future trends in waste minimization. In addition, the study identified the current incentives and disincentives (i.e., economic, regulatory, and technical) which exist for waste minimization.

For the next several years, the OSW will be developing and implementing the Agency's waste minimization program which was introduced in the Report to Congress. The goal of this program is to promote the national policy established in the Hazardous and Solid Waste Amendments of 1984 regarding the minimization of hazardous waste.

As it is presently structured, the program has two principal objectives: (1) evaluate the need for regulations for waste minimization and present this evaluation along with appropriate recommendations in a report to Congress in 1990; and (2) foster the use of waste minimization through technology transfer and information dissemination activities. In order to ahieve this goal, OSW has developed its FY87 and FY88 programs to focus on the tasks of gathering information and data to establish trends in waste minimization and developing information dissemination/ technology transfer activities.

Office of Research and Development. The Office of Research and Development (ORD) has supported a small waste minimization extramural program over the past few years, cooperated with the states of North Carolina and Minnesota in supporting programs to assist small businesses to minimize their wastes, and cooperated with the Governmental Refuse Collection and Disposal Association (GRDCA), a trade association concerned with providing technical assistance to small waste generators. Modest funding for the two state and trade association cooperative agreements has totaled $420K over two fiscal years. Matching funds by the states has brought a significant increase in the funding to allow for a substantial federal-state-private sector relationship.

ORD has also provided rather substantial support to one of the Agency's Centers for Excellence, the Illinois Institute of Technology (IIT), to support fundamental research into industrial waste elimination. The EPA has also cooperated closely with the Tufts Center for Environmental Management to support various waste minimization studies and conferences. HWERL projects to evaluate various recycling options in the printed circuit board industry and several smaller projects to carry out waste minimization audit studies at five manufacturing facilities have recently been completed. Currently, as a continuation of the audit studies program, the ORD is supporting the development of a manual to be used in carrying out waste minimization audits. Funding for the audit program has remained constant at approximately $200K per year for the past two fiscal years. The IIT program has expended some $1.5 million since 1978 to support many broad-scale waste elimination research projects and some $250,000 has been provided by the Agency to the Tufts Center to support waste minimization projects.

Current Activities

There is presently underway within the EPA the development of an Agency-wide strategy to convert into action the goals and policies of the EPA Report to Congress, and to provide a technical foundation for furthering the acceptance of technologies that reduce the generation of hazardous waste.

Overview of the Multi-Option Model: A Computerized Waste Reduction Information and Advisory System

Presented by
Frank M. Brookfield
Data Management Specialist
Illinois Department of Energy and Natural Resources
Savoy, Illinois

(Originally Exhibited at Illinois Hazardous Waste Reduction '87
September 22-23, 1987)

Overview of the MULTI-OPTION MODEL (MOM): A Computerized Waste Reduction Information and Advisory System

The Multi-Option Model (MOM) is an interactive computerized waste management tool originally developed by ICF Technology, Inc. for the Maryland Hazardous Facilities Siting Board and the USEPA. Its primary purpose is to assist generators and state technical assistance officials with the completion and analysis of technologies and methods for the reduction, reuse and treatment of solid and hazardous waste. Recently the Illinois Hazardous Waste Research and Information Center (HWRIC) contracted with ICF Technology, Inc. for further development of two components of the MOM.

As shown in Figure 1, the MOM is envisioned to consist of three components, a Waste Reduction Advisory System, a Treatment, Storage and Disposal Advisory System, and an interactive Waste Exchange service. The Waste Exchange component is not currently developed. The other two components exist but have only partially developed data bases and have had limited field evaluation. Additional development is being undertaken and suggestions for revisions are welcome.

The Waste Reduction Advisory System

The Waste Reduction Advisory System (WRAS) currently consists of a Waste Reduction Audit Checklist (WRAC) developed for the Illinois HWRIC and an Information Base. These components and the general types of information they contain are illustrated in Figure 2. The WRAC consists of information on the seven waste reduction topics listed in Table 1. These topics range from low capital approaches to those that are more costly such as equipment or process modification, and cover options from the beginning of the industrial process through waste production and reuse. The information in the WRAC is intended to introduce the user to the full range of types of waste reduction alternatives that may be appropriate. More detailed waste reduction case studies are included in the following Information Base section of the WRAS.

For each topic in the WRAC the user is first asked if his/her company has ever tried that approach (for example, conducted a waste audit). If the user answers yes, the next screen asks general questions about the results. If that approach has not been tried, the user is asked to indicate the reasons why. The WRAC also contains a definition screen for each topic and a screen where a user can request additional information and/or technical assistance.

The WRAS Information Base contains descriptions of waste reduction applications from literature and documented case studies. Information is shown on potential waste reduction measures tailored to either the unit processes (across industrial categories) or by a particular industry as selected by the user. The user is first shown several headline descriptions of the information. More details can be requested in associated abstracts and citations. Ultimately, the literature cited in the WRAS Information Base will be accumulated in a clearinghouse.

The Treatment, Storage and Disposal (TSD) Advisory System

Based on information specified by the user regarding waste type and facility location, the TSD component of the MOM model provides an array of waste management options and cost estimates. Guidance is given on:

- Applicable treatment technologies;
- Available facilities;
- Engineered costs for transportation, treatment, and disposal;
- Recycling opportunities; and
- Waste handling brokers.

Most of the information in the TSD data base on management options for wastes currently is for facilities and services in the northeastern states. The Illinois HWRIC-sponsored study enhanced the TSD system by adding a price query to allow waste management service price/cost comparisons. The engineered cost estimation component was also improved by accounting for economies of scale for the transport of less-than-truckload waste quantities.

Further Information

More information on this computerized waste reduction system can be obtained by writing or calling the following:

Illinois Hazardous Waste Research and Information Center
1808 Woodfield Drive
Savoy, Illinois 61874
(217) 333-8940

Figure 2:
WASTE REDUCTION ADVISORY SYSTEM

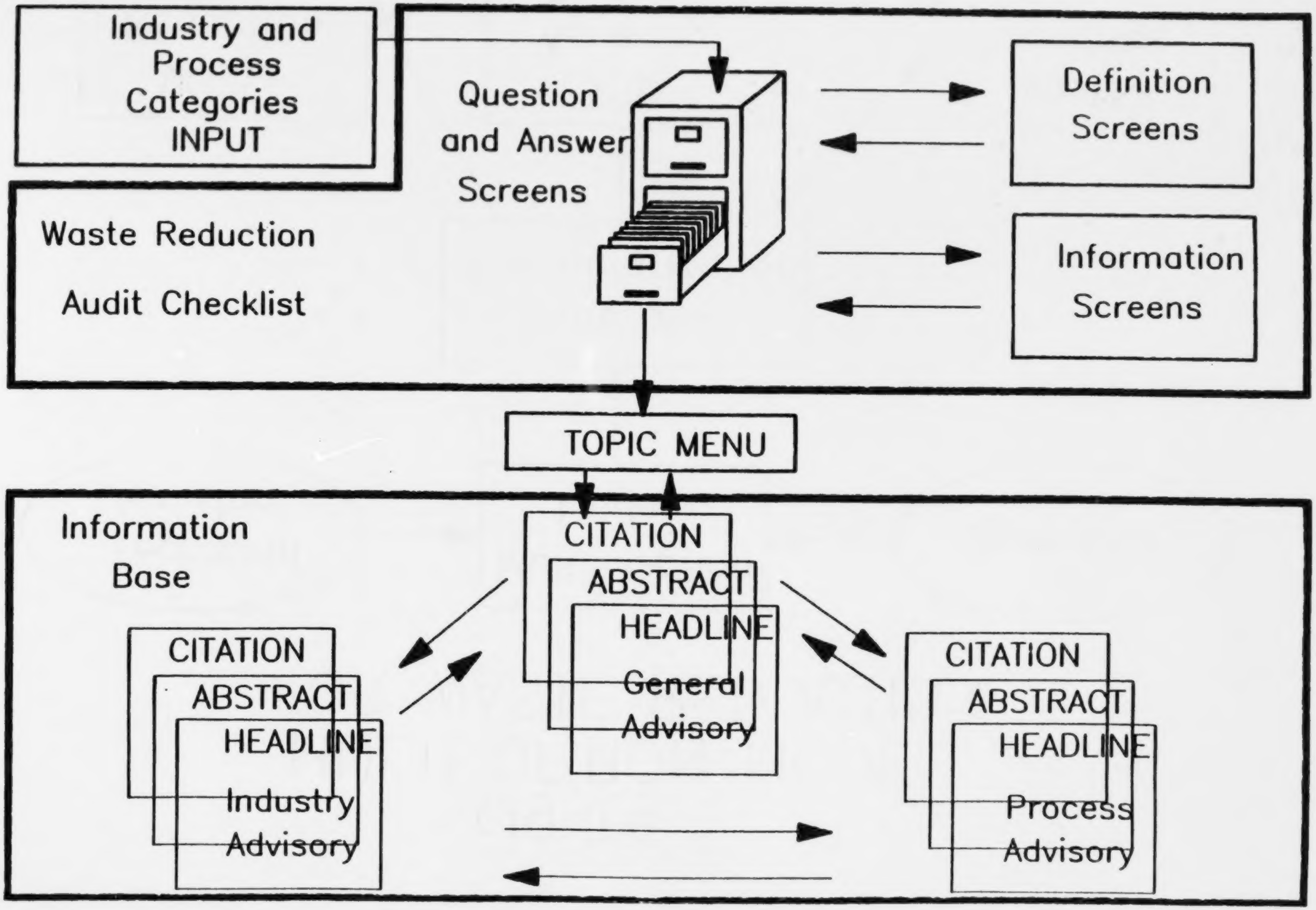

Figure 1:
MULTI OPTION MODEL
FOR WASTE REDUCTION

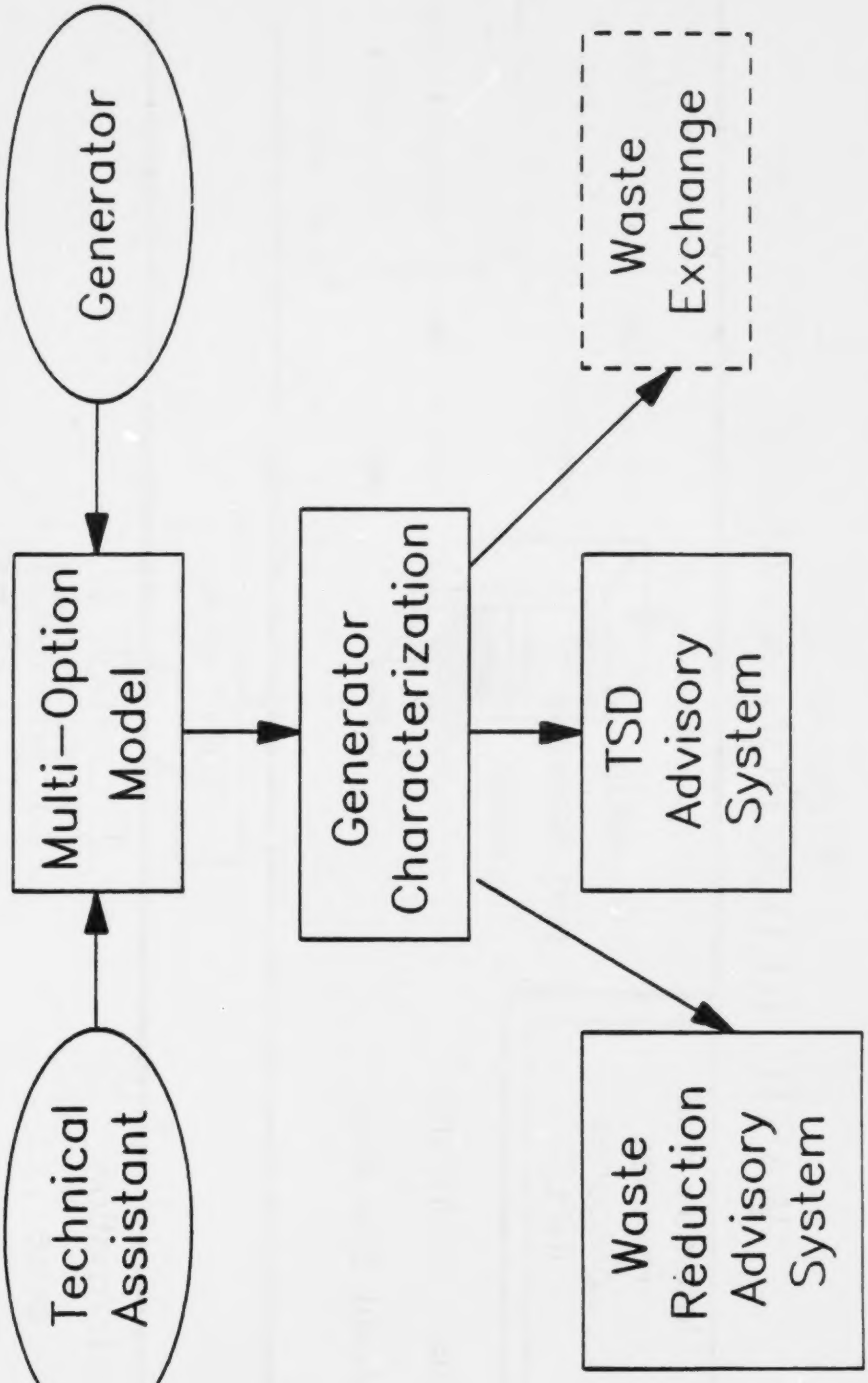

Figure 3:
TSD Advisory System

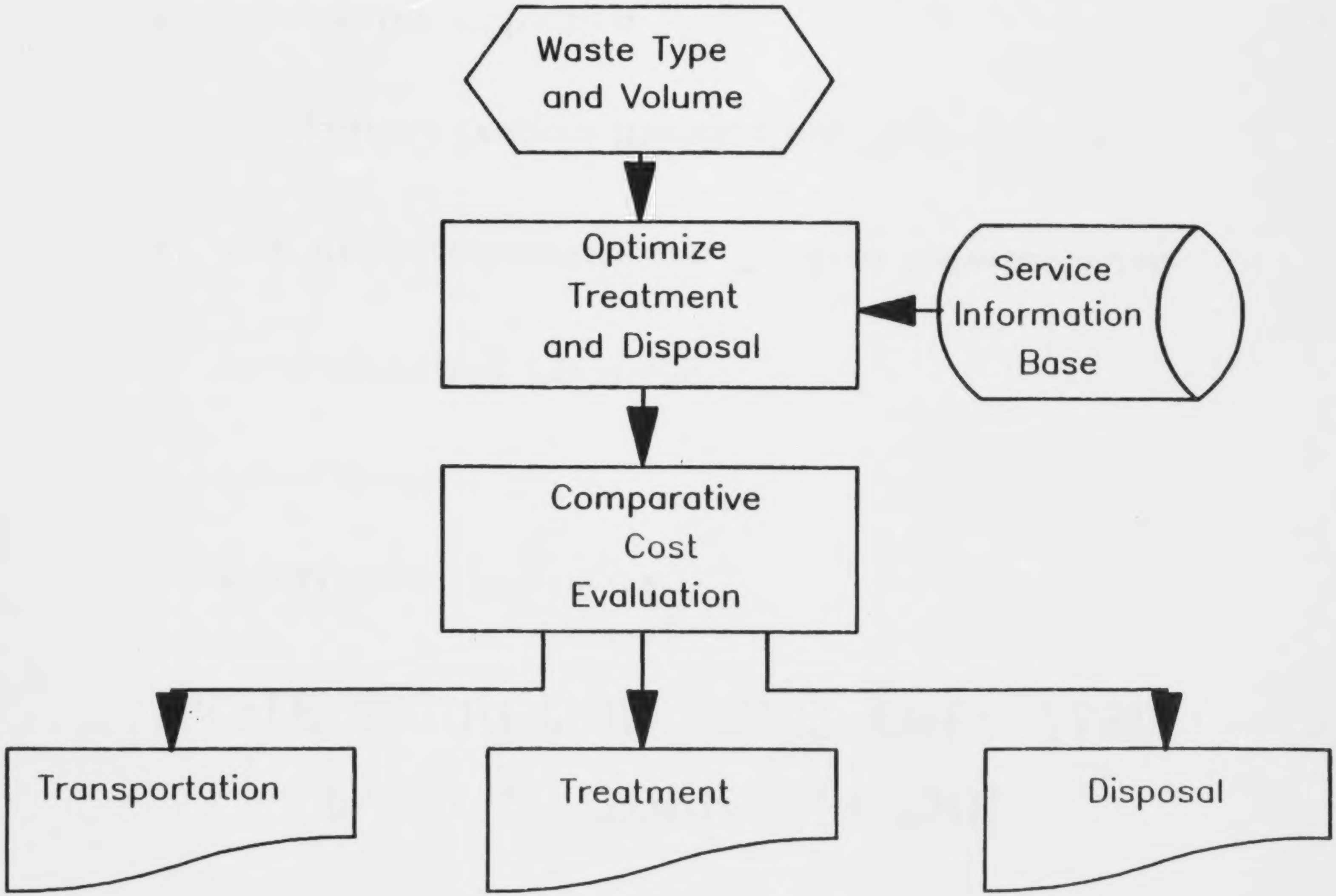

Table 1: TOPICS IN THE WASTE REDUCTION AUDIT CHECKLIST

1. **Management Strategies**
2. **Waste Audit**
3. **Good Operating Practices**
4. **Raw Material Substitution/Product Reformulation**
5. **Equipment/Process Modification/Replacement**
6. **Wastewater Reduction**
7. **Resource Recovery**

Hazardous Waste Minimization at Olin Corporation

Presented by
R. E. Mooshegian
Environmental Coordinator
Olin Corporation
East Alton, Illinois

HAZARDOUS WASTE MINIMIZATION
OLIN CORPORATION
EAST ALTON, IL

Olin Corporation operates two manufacturing facilities in East Alton, IL that generate, treat and/or store hazardous waste. They are referred to as the Main Plant Facility and the Zone 17 Facility.

The Main Plant Facility includes manufacturing operations conducted by the Brass Group and by the Defense Systems Group, Winchester Division. The Zone 17 Facility includes manufacturing operations conducted by the Brass Group and by Olin Electronics Materials Corporation (OEMC), a wholly owned subsidiary of Olin Corporation. The Brass Group manufactures brass and copper alloy products. Winchester manufactures small arms ammunition and explosives. OEMC manufactures clad-metal strip used for the manufacture of electronic components.

Olin's waste minimization program addresses the criteria set forth by Congress under Section 3002 of RCRA by (1) reducing the volume or quantity and toxicity of hazardous waste to the degree determined by Olin to be economically practicable and (2) treating, storing, or disposing of the hazardous waste generated using methods that minimize the present and future threat to human health and the environment. Olin's program also addresses recently enacted legislation by the State of Illinois which severely restricts the landfilling of any hazardous waste unless specific authorization is granted by the Illinois EPA.

Specifics of the program include an annual review of the following items for each hazardous waste generated:

1. Review of raw materials used in the process that generates the waste to determine if other materials can be used that will render the waste non-hazardous.

2. Review of the current management practices used to treat/store/dispose of the waste to determine if a better alternative can be instituted.

3. Discussions with department(s) that generate the waste to determine what measures can be implemented to reduce the volume and/or toxicity of the waste.

Overall potential improvements identified as a result of this program are presented to Olin management to obtain approval for implementation.

To date, three major hazardous waste minimization projects have been identified and presented to management for approval. The projects are:

1. Installation of a belt filter press at the Main Plant Zone 6 Wastewater Treatment Facility (WWTF) to replace a rotary drum vacuum filter used for sludge dewatering. The belt press dewaters more efficiently than the vacuum filter resulting in a reduction in the volume of hazardous sludge that must be landfilled.

2. Segregation of the hazardous wastewater discharges from the non-hazardous wastewater discharges that are currently combined before they enter the Zone 6 WWTF and cause the dewatered sludge to be a listed and characteristically hazardous waste. The listed hazardous wastewater discharges, which make-up approximately 4% of the total volume of wastewater treated at the Zone 6 WWTF, will be redirected to a second, new and smaller wastewater treatment plant that will also be located in Zone 6. Once the new wastewater treatment plant is operational, the volume of hazardous sludge that must be landfilled will be reduced by as much as 91%.

3. Construction of a new chemical fixation facility that will convert 1,500 cubic yards per year of characteristically hazardous waste to non-hazardous waste.

Olin management has already approved the monies necessary to implement the first two projects and has also approved the money necessary to begin operation of a pilot plant to develop the needs for a full scale chemical fixation facility planned to be operational in 1988.

A detailed discussion of Olin's manufacturing operations and the three major waste minimization projects follow:

DISCUSSION OF WASTE MINIMIZATION PROJECTS:

As stated previously, Olin Corporation's Main Plant Facility (MPF) is made-up of manufacturing operations conducted by two operating divisions, referred to at the Brass Group and the Defense Systems Group. Process wastewater discharges from these operations currently discharge into the MPF's process sewer system which in turn leads to one centralized wastewater treatment plant referred to by Olin as the Zone 6 Wastewater Treatment Facility (WWTF). The Zone 6 WWTF influent flow averages 3.5 million gallons per day. A very small percentage (approximately 4%) of the Zone 6 WWTF influent comes from hazardous processes. The MPF also operates its own potable water plant, which is referred to as the Filter Plant. The Filter Plant's primary source of raw water is the Mississippi River. The Filter Plant produces 4 to 5 million gallons of potable water per day. Filtered river solids from the water plant are also discharged into the MPF's process sewer system.

The processes that discharge hazardous wastewater include electroplating operations and explosive manufacturing operations, all of which are listed hazardous waste processes. Since the listed hazardous wastewater is combined with all of the non-hazardous wastewater from the rest of the Main Plant's manufacturing operations, the influent to the Zone 6 WWTF is considered a hazardous waste.

The operation at Zone 6 consists of both physical and chemical treatment processes. The influent pH is normally in the range of 4 to 6. Lime is added to the wastewater for pH adjustment and formation of insoluble metal hydroxides. Treatment pH is in the range of 9 to 9.3. With the aid of polymers the insoluble solids settle to form a sludge. The treated wastewater effluent is then discharged into the East Fork of the Wood River. The sludge, referred to as Zone 6 WWTF Sludge, is thickened, dewatered by using vacuum filtration and placed into roll-off type dumpsters that are routinely hauled off-site to a hazardous waste landfill. Over the last six years, an average of 8,300 cubic yards (yd^3) of sludge per year has been sent to off-site hazardous waste landfills.

Since the Zone 6 WWTF Sludge represents the largest single source (80%) of hazardous waste that is generated at Olin's East Alton Facilities and sent to off-site hazardous waste landfills, reducing its volume has been given top priority by Olin management to comply with the intent of Section 224 of the 1984 Amendments to the Resource Conservation and Recovery Act and the prohibition on the landfilling of hazardous waste after January 1, 1987 set forth by Section 39(h) of the Illinois Environmental Protection Act.

The two waste minimization projects described below deal directly with reducing the volume of Zone 6 WWTF Sludge.

Belt Filter Press

The first project, the use of a belt filter press for dewatering, came about as the best method to solve the problem of free-running liquid in the Zone 6 WWTF Sludge.

Up until November, 1985, Olin sent most of the hazardous waste it generated to a permitted facility about twenty miles from East Alton. However, the landfill closed in November, 1985 which meant that Olin had to start sending its hazardous waste to the next closest facility which was 170 miles away. Soon after the Zone 6 WWTF Sludge was being sent to the new landfill, some loads were returned to Olin due to free running liquids. At first, it was thought that there might have been a problem with the vacuum filters which were used for dewatering. However, careful examination of the sludge being discharged from the vacuum filter and into the dumpsters indicated no free running liquids. If a dumpster of sludge left Olin "dry" but had free running liquid in it after arriving at the landfill, then the vibration of the dumpster during the trip must have caused some of the moisture in the sludge to leach out.

Initially, this problem was fought by dumping up to as much as 1,000 pounds of lime in the dumpster to absorb any free running liquid that leached out of the sludge during the trip to the landfill. However, this became very time consuming and did not always guarantee that a load of sludge would not be returned to Olin. As a result, it became apparent that some other way of eliminating this problem must be found.

The vacuum filters at Zone 6 normally dewater the sludge to a solids content of 30% to 35% which is effectively at the limit of their capability. To eliminate the free running liquid problem, some type of filtration equipment more efficient that a vacuum filter would be required. Several types of filters were considered, including cake presses, plate & frame filter presses, and belt filter presses. Based on laboratory tests conducted on the Zone 6 WWTF Sludge, the belt filter press produced the driest filter cake, which had a solids content of about 50%. To assure that the filter press would dewater just as efficiently on a larger scale as in the laboratory, a pilot unit was leased and brought to the Zone 6 WWTF. The small press performed quite well and indicated that it could reduce the volume of hazardous sludge generated by the vacuum filters by approximately one-third or 2,700 yd^3 per year.

A full size filter press was purchased in May, 1986 and began operating at the end of the year. Based on the first nine months of operation in 1987, the filter press is performing better than expected and has reduced the volume of sludge generated at the Zone 6 WWTF from a six year average of 8,300 yd^3 per year to a volume of about 5,400 yd^3 per year (pro-rated for 1987). The belt filter press performance equates to a 35% reduction in the volume of sludge to be disposed of.

Hazardous Waste Stream Segregation

The second waste minimization project designed to reduce the volume of Zone 6 WWTF Sludge involves the physical segregation of all hazardous wastewater discharges at the Main Plant from all non-hazardous wastewater discharges. The hazardous wastewater discharges will be isolated and redirected to a second, new and smaller wastewater plant that will also be located at Zone 6.

As stated in the beginning of this paper, a very small percentage (4%) of the wastewater that is generated at the Main Plant comes from hazardous processes. However, since the wastewater comes from listed hazardous waste processes and because it is mixed with non-hazardous wastewater, the entire wastewater influent to the Zone 6 WWTF and the sludge that comes out of the facility are considered to be hazardous wastes.

Because of the constantly rising prices for the landfilling of hazardous waste, and more importantly because of the environmental liability associated with landfilling, Olin looked at several different methods to further minimize the volume of Zone 6 WWTF Sludge including incineration and a delisting petition as well as the segregation of the wastewater discharges. The listed hazardous waste processes at the Main Plant include electroplating and explosives manufacturing operations. Since the wastewater generated by all of the hazardous processes is pretreated before it is discharged into the process sewer system, consideration was given to whether or not a delisting petition could be obtained for the Zone 6 WWTF Sludge. However, based on sampling and analyses conducted upon all of the listed process wastewater discharges and Zone 6 WWTF Sludge, it was determined that the sludge would sometimes fail the EP Toxicity test for lead. The lead comes from the manufacturing of explosives and the chemical treatment and breakdown of explosive containing waste. There are no substitute raw materials to take the place of the lead bearing compounds necessary for the manufacture of explosives.

Incinerating the Zone 6 WWTF Sludge was considered since 65% - 70% of the sludge is water. However, incinerators are expensive to operate and maintain and would have to comply with the USEPA's stringent RCRA Subpart O rules. Additionally, because the Zone 6 WWTF is in a remote area of the Main Plant, the waste heat from incineration could not be reused. Finally, an incinerator will not destroy the lead contained in the sludge and would possibly require costly air pollution control equipment.

The only viable alternative to significantly reduce the volume of Zone 6 WWTF Sludge was to segregate all of the hazardous wastewater discharges from the non-hazardous and treat them separately. An engineering firm was selected to perform a treatability study and provide the design development of the treatment system. The following describes the activities conducted in the development of this option.

The first step in the treatability study was to determine the type of samples required. Since most of the sources to be sampled had continuous discharges it was decided to collect composite samples. Automatic samplers were set up at each source and adjusted to collect 30 gallon samples over a 24 hour period. A series of flow measurements were taken during sample collection to establish minimum and maximum flows from each source for design purposes. Production data was also collected to determine if normal production activities occurred during sample collection. After the samples were collected they were composited on a flow proportional basis using average flow. The samples were then sent to the lab where they were prepared for testing. Once at the lab the samples were analyzed for selected parameters to determine the wastewater characteristics.

In order to determine the optimum treatment process a series of screening tests were performed. These screening tests indicated which treatment technologies should be further investigated. The technologies evaluated included oxidation with ozone (with and without ultraviolet light), ion exchange and chemical precipitation. After treatment each sample was analyzed for dissolved lead. Dissolved lead was chosen as the indicating parameter for treatment efficiency due to the low discharge limits for total lead expected in the NPDES Permit. The samples treated with ozone resulted in very high dissolved lead levels. The ozone caused a drop in pH and therefore resulted in placing the lead in solution. Analyzing of the samples after ion exchange treatment indicated only a 50% reduction in the dissolved lead concentration. In evaluating chemical precipitation a pH range of 6 to 11 was investigated. Calcium hydroxide and sodium hydroxide were tested as precipitants. The tests indicated that dissolved lead concentrations of 2.0 ppm could be achieved by treatment with either chemical at a pH range of 9.0 to 9.5. Based on these results it was decided to develop the chemical precipitation process.

One objective in the development of the treatment process was to make it compatible with the Zone 6 WWTF to take advantage of existing equipment. The Zone 6 WWTF uses lime for precipitation therefore it was decided to use lime for the new treatment system and avoid the cost of another chemical feed system.

The next step in developing the chemical precipitation process was to determine the level of treatment that can be achieved. The use of a coagulant followed by pH adjustment with lime was evaluated. The coagulants investigated included magnesium sulfate, aluminum sulfate, ferric chloride and ferrous sulfate. Magnesium and aluminum sulfate produced a fine particle which would not settle out on its own. Ferric chloride and ferrous sulfate produced particles which settled well and resulted in acceptable dissolved lead concentrations. However, the solids generated by treatment with ferric chloride began to resuspend. Based on the tests it was decided to optimize the use of ferrous sulfate.

In order to determine the optimum ferrous sulfate dosage a series of tests were set up. The ferrous sulfate dosage was varied from 325 to 400 ppm and the treatment pH was in the 9.0 to 9.5 range. After treatment, each sample was analyzed for its dissolved lead content. The analysis indicated that at a ferrous sulfate dosage in the range of 375 to 400 ppm a dissolved lead concentration of 0.10 ppm could be achieved.

Coagulation followed by precipitation produced some fine particles which did not settle well. It was apparent that a polymer would be needed to aid in settling. Based on past, in-house experience, a high molecular weight anionic polymer was needed. In order to determine the optimum polymer dosage another set of tests were performed. A sample of the wastewater was first treated by adding ferrous sulfate to a concentration of 400 ppm. The pH was then adjusted to 9.3 with calcium hydroxide to begin formation of a micro-floc. With the sample thoroughly mixed portions were taken for the addition of polymer. Polymer was added to each portion at dosages that ranged from 1 to 10 ppm. Each portion was rapid mixed (100 rpm) for one minute and then mixed slowly (15 rpm) for flocculation. At this rate, a slow, gentle motion of the particles resulting in good floc formation was observed. After a flocculation time of ten minutes the portions were then poured into graduated cylinders to determine the rate of settling and the volume of sludge generated. From these tests it was determined that a polymer dosage of 2.0 to 4.0 ppm was the best. To further evaluate the use of polymers, several manufacturers were investigated. The results indicated that as long as a high molecular weight anionic polymer was used good settling could be achieved.

The main objective of this project was to substantially reduce the volume of hazardous sludge generated. The next step was to evaluate the new treatment process to determine if the sludge generation rate could be reduced without sacrificing treatment. After reviewing the process it was decided to substitute sodium hydroxide for calcium hydroxide. Another set of samples were treated as previously described substituting the sodium hydroxide. The samples were analyzed with the results indicating acceptable lead treatment and a sludge generation rate 50% less than that of calcium hydroxide. Magnesium hydroxide was also investigated however treatment was not as good. Sodium hydroxide was then selected as the treatment chemical for pH adjustment.

In order to verify this process a series of grab samples were collected and treated. This time the treated samples were analyzed for all metals for which NPDES monitoring would be required. The test results indicated that the treatment process should meet the anticipated NPDES limits.

Having identified the optimum treatment process the next step was design development of the treatment system. Collection of the wastewater was complicated by the fact that the sources were scattered throughout a 500 acre manufacturing facility. It was decided to provide a central collection point for the wastewater and from there pump it to the treatment equipment. After evaluating the sources it was determined that all but one source would require its own pump station. To further complicate the project, more than half of the piping for the transmission system would have to be above ground requiring the piping to be heat traced and insulated. Because of the potential of corrosion, 304L stainless steel was selected for most of the above ground piping. Due to the presence of chlorides from the copper plating operation, it was decided to use 316L stainless steel to prevent stress corrosion cracking. For the underground piping PVC was selected.

Due to the potential for stringent discharge limits for lead it was decided to solicit proposals from wastewater treatment equipment manufacturers. Samples of the wastewater along with the expected NPDES limits were sent to several manufacturers for their evaluation. Only one manufacturer indicated that their equipment could meet the discharge limits and were willing to guarantee them with the use of a dual media pressure filter. The preliminary design was submitted and approval given for final design.

Upon completion of final design a contractor was selected and construction began in July, 1987 with plant start-up in October, 1987. The treatment system consists of the following:

i) Five individual source pump stations
ii) Two main collection pump stations
iii) 9,200 feet of force main
iv) Two 10,000 gallon influent wet wells
v) Chemical feed systems
vi) Wastewater treatment equipment
vii) Sludge dewatering equipment

The end result of this waste stream segregation project is a reduction in the volume of hazardous waste generated at the Zone 6 WWTF will from 5,400 yd^3 per year to less than 500 yd^3 per year. This project coupled with the belt filter press will result in a 94% reduction in the volume of hazardous waste generated by Olin and landfilled in Illinois.

Chemical Fixation

The third major waste minimization project identified by Olin involves the installation and operation of a chemical fixation facility that will convert approximately 1,500 yd^3 per year of characteristically hazardous waste to non-hazardous waste.

This project was initiated in mid-1986 in order to comply with Section 39(h) of the Illinois Environmental Protection Act which prohibits the landfilling of any hazardous waste after January 1, 1987 unless specific authorization is granted by the Illinois Environmental Protection Agency. The Agency cannot grant authorization unless the generator of the waste demonstrates that considering technological feasibility and economic reasonableness, the waste cannot be recycled for reuse, incinerated, or chemically, physically, or biologically treated so as to neutralize and render the waste non-hazardous.

The hazardous waste streams generated by Olin that are applicable to the landfill ban include:

Zone 3 Incinerator Ash - generated by two incinerators that burn factory trash & certain Special Wastes. The waste heat is converted into process steam for use in manufacturing. The waste is hazardous due to EP Toxicity for lead. The source of lead comes from the contamination of combustible materials throughout the small arms manufacturing areas at the Main Plant. Lead and/or lead bearing compounds are used to manufacture lead shot, lead bullets, and explosives.

There is not enough lead present in this waste to consider recycling. The only means to render it less hazardous or non-hazardous is to subject it to chemical fixation.

Zone 3 Baghouse Dust - generated by two baghouses that are used to control particulate emissions generated by the two Zone 3 Incinerators. The waste is hazardous due to EP Toxicity for lead. The source of lead is the same as for Zone 3 Incinerator Ash. There is not enough lead present to consider recycling.

However, about one-third of the dust is lime dust (lime is injected upstream of the baghouses to control HCl emissions). Olin is considering the reuse of the baghouse dust as a source of lime for other processes, but if a beneficial reuse of the dust cannot be found, it will be subjected to chemical fixation.

Ballistics Sand - generated by the test-firing of projectiles into bunkers of sand. The waste is hazardous due to EP Toxicity for lead. The source of lead is the lead bullets and lead shot used to manufacture small arms ammunition. There is not enough lead present to consider recycling. Olin plans to install a screening operation that will remove the larger pieces of lead and allow the reuse of most of the sand. However, the non-reusable portion of sand will be subjected to chemical fixation.

Tumbling Media - generated through the cleaning of certain types of small arms ammunition. The source of lead is the lead bullets used to manufacture small arms ammunition. There is not enough lead present in this waste to consider recycling, however, since most of the waste is made-up of organic media, incinerating it could substantially reduce its volume even though it would not render the waste non-hazardous. In February, 1987, Olin began incinerating this waste at the Zone 3 Incinerator facility. Unfortunately, after many attempts to incinerate this waste over a period of three months, it became obvious that Tumbling Media could not be treated in this manner without severely affecting the operation of the incinerators. The major problem encountered was the melting of the lead contained in the waste (lead melts at 620°F and the lower chamber temperature in the incinerator is usually about 1,600°F) as soon as the waste was charged into the incinerator. The lead clogged the underfire combustion air vents and quickly shut down the incinerator. For this reason the Tumbling Media will be subject to chemical fixation.

To determine the best technology available to chemically fixate EP Toxic waste, Olin consulted with several different companies who commercially offer these types of treatment services as well as searching through published reports and literature to determine the chemistry involved with chemical fixation.

It quickly became evident that by mixing EP toxic wastes with Portland cement and a binder to encapsulate the heavy metals, the wastes could easily be rendered non-hazardous. Olin performed its own laboratory tests upon each of the waste streams to develop the chemical recipes necessary to make the wastes non-hazardous. Based on the lab tests, Olin discovered that all of the wastes could be rendered non-hazardous and disposed of at a sanitary landfill for less money than it costs right now to send the untreated waste to a hazardous waste landfill.

This result and the Illinois EPA landfill ban justified monies to install a chemical fixation pilot plant. The pilot plant began operating on August 3, 1987 and will operate until the end of November, 1987. The results obtained from the pilot plant will be used to design a full scale chemical fixation treatment facility that Olin plans to put into operation on or about August 1, 1988. The Illinois EPA has granted Olin authorization to continue to landfill its EP Toxic waste untreated until the treatment facility is put into operation.

Once all three waste minimization projects have been implemented, Olin will have reduced the generation of hazardous waste at its East Alton, IL facilities by 95%, or 9,300 yd^3 per year.

Waste Reduction at the Campbell Soup Company

Presented by
Ted Birchmeier, Area Manager
Container Manufacturing
Campbell Soup Company
Camden, New Jersey

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The system that we had put into effect worked as follows:

A. Log all material received.

B. Mark each container clearly regarding its contents.

C. Report all activity shipped.

D. Log daily all hazardous waste shipped to storage areas.

E. Audit all areas daily.

That is a simple overview, to actually put it into effect was a task in itself.

One of the first steps taken to get the system started, was meetings with the actual people that handle the materials. Once all the input was gathered we were able to set up our Hazardous Waste System.

All materials received went to a predetermined storage area. We then could keep track of all incoming materials. Then we had the receiving and shipping clerk generate a weekly report of all activities. The hazardous waste that we made could be calculated by the usage of materials received.

We designated two storage areas to accommodate our hazardous waste. We collected waste in three 55 gallon drums, one which was marked solvent, another marked water and the third container marked cleaning material. When the empty drums were put into the storage areas the date and name tags were affixed to the drums.

When the drums became filled then the Hazardous Waste stickers were placed on the side of the drums with the appropriate information, they then were shipped to the storage area. We shipped out of the plant every 40 days in which 80 drums were sent to our TSDF (to assure we were in compliance we would audit the TSDF site twice a year). After inspecting the storage areas both the shipping clerk and the supervisor would enter their findings in a daily log book.

In 1984 we started a program to reduce the amount of hazardous waste generated. We investigated the alternatives to cleaning materials, one of our suppliers came up with a cleaning material to replace our cleaning solvent.

Our next project was to find a means of recovering our solvent in the coating operation. With the aid of our Quality Circle group we found a recovery system which recovered the solvent at a rate of 8 gallons per hour, at a cost of $.10 per gallon, the material was 99.5% pure.

A Corporate decision was made to discontinue the manufacturing of containers at the Camden Plant. We are currently phasing out our hazardous waste area.

A Waste Audit Workshop for the Vehicle Maintenance Industry

Presented by
Robert H. Salvesen, Ph.D.
S&D Engineering Services, Inc.
Metuchen, New Jersey

Hazardous Waste Management Waste Reduction Audit Workshop

Vehicle Maintenance Industry

1. Introduction

This paper will cover the following aspects of the vehicle maintenance industry.

- Types of oils, solvents and other materials used
- How wastes are generated
- Nature of wastes generated
- Reclamation options
- Waste Reduction Practices and Examples

Proper management of the materials used can result in significant reduction in the volumes and costs of wastes to be disposed. In order to accomplish these objectives, it is helpful to get a better understanding of what materials are used, and handling, treatment, recycling and disposal options that are available.

2. Types of Oils, Solvents and Other Materials Used

2.1 Oils

The types of oils generated in vehicle maintenance are obviously those necessary for functioning of the various types of vehicles. These may be categorized mainly as lubricating, hydraulic and transmission oils. In addition, some other oils may be generated in large vehicle maintenance operations, such as cutting and cooling oils. For our purposes today, I would like to classify these oils by three types:

- Engine Oils
- Non-engine Oils
- Water Soluble Oils (emulsion)

Reasons for these classifications will be evident in the following discussions, but briefly the lube oils in combustion engines pick up a broader range of contaminants than the non-combustion engine oils. Water soluble oils are obviously different.

2.1.1 Engine Oils

Lubricating oils for both gasoline and diesel internal combustion engines are the major types of oils used. The major differences in these oils are the type and amounts of additives used. All are available in different viscosity grades. Most lube oils are made from petroleum and contain hydrocarbons of various structures. These oils are generally made from either paraffinic or naphthenic base stocks. Paraffinic oils are composed of straight chain hydrocarbons, naphthenic oils are mixtures of various cyclic and branched chain hydrocarbons. Synthetic oils are composed of compounds called esters, which are generally made from the reaction of organic acids and long chain alcohols.

All lube oils contain additives to impart specific properties to the various oils. The additive materials commonly used include:

- Metallic salts of sulfuric acid (ie) Barium, Calcium salts of organic sulfonates
- Metallic salts of phenol derivatives and phenyl sulfide derivatives
- Metallic salts of naphthenic and carboxylic acids
- Polymers of methacrylic esters and amides
- Imides of polymeric acids

These additives can be present from 0.1 - 20+ wt. %, depending upon the severity of the application.

Some of the major differences in lube oils are as follows:

- Gasoline Truck Engine Lubricants - Requires somewhat higher relative detergency than passenger car lubricants and high viscosity index (VI) to ensure good cold-starting characteristics.
- Diesel Engine Lubricants - Diesel engines require a relatively high level of detergency to minimize the effect of soot formation in the combustion chamber. In addition, the high compression ratio of diesel engines creates very high piston ring zone temperatures. This requires lubricants with good oxidation stability (paraffinic-base stock). Diesel lubricants can use high alkaline detergent additives to neutralize some of the effects of diesel fuels with relatively high sulfur content.
- Aviation Piston Engine Lubricants - Aviation piston engines require very good oxidation stability and high VI. Thus, lubricants for this service are parrafin-base stocks and usually contain oxidation inhibitor and dispersant additives.

  From the standpoint of reclamation and handling of used petroleum-based lubricants, the greater the levels of detergents and dispersants, the greater the tendency of these materials to form emulsions which may be difficult to treat for water and solids removal. Diesel and heavy-duty piston engine lubricants may be more of a problem than lubricants for passenger vehicles.

2.1.2 Non-Engine Oils

Used hydraulic and transmission oils are the major oils in this classification that are produced in this industry. Hydraulic fluids are either petroleum based oils or synthetic fluids. The petroleum oils are similar to engine lube oils, but generally contain less and different additions. Synthetic hydraulics fluids designated as fire-resistant fluids generally consist of phosphate-esters, polyglycols, polyolefins, silicones, silicate esters, and halogenated hydrocarbons such as chlorofluorocarbon polymers, fluoroesters and blends of these compounds.

These materials can generally be designed (by modification of chemical structure) to have a broad range of properties without the use of additives. Chemical complexity and diversity of the above types of used oils sometimes makes it beneficial to separate these synthetics from petroleum-base used oils. This is especially true if enough used material is generated to sell to a recycler.

2.1.3 Other Oils

This category includes cutting, machine, quench, forging and a wide variety of neat and emulsified oils. The neat oils can be mixed with other oils and recycled as described below, but emulsified oils and oil/water emulsions need to be handled separately. The latter are more difficult to recycle and there are a number of suppliers who provide equipment for this purpose.

2.2 Solvents

The major solvents generated by the vehicle maintenance industry may be classified as follows:

- General purpose cleaners
- Carbon removers and paint strippers
- Paint Thinners
- Halogenated Solvents

A discussion of the types of materials used follows.

2.2.1 General Purpose Cleaners

Hydrocarbon solvents are most commonly used for this purpose. They may be called by different names, but are generally very similar in properties. In the petroleum industry they an designated as mineral spirits or naphtha. However, some products may have additives which appeal to individual shops and are preferred over other products. For example, some products may contain the following types of additives:

- Detergents - these can provide better penetration of oil and grease on automotive parts and also allow water washing for cleanup.
- Lanolin - this and other similar additives may be added to leave a residue on the skin to reduce skin irritation.
- Color and perfumes - to provide a recognizable more attractive product.

There can be some real differences in the basic properties of petroleum products used for these purposes, however, the industry usually does not distinguish among them. For example, the higher the aromatic content of the mineral spirits, the better the solvent power.

Products supplied by service organizations, such as, Safety-Kleen and others are general purpose hydrocarbon based cleaners.

Other solvents used are noted below along with brief comments:

- High flash naphtha - this is a petroleum hydrocarbon with a Flash Point above 140 F to provide an added safety factor. All petroleum general purpose cleaners such as those noted above should have a Flash Point of 100 F minimum.
- Odorless solvent - some shops have been found to use an odorless paint thinner for general purpose cleaning. While this solvent smells nice and can do a good job, it takes more "elbow grease" to remove oil and

grease and also costs more.

- Safety solvents - these may be a High Flash naphtha such as noted above, or a blend of hydrocarbon and chlorinated (i.e. Methylene chloride) or Freon solvents. Such solvents can serve a very useful purpose, and may be required in some applications. However, solvents containing chlorinated or Freon solvents are often not desired for engine uses because of the concern for corrosion if left in engine components. Freon solvents are less of a concern than chlorinated solvents.

2.2.2 Carbon Removers and Paint Strippers

While these products differ in some respects, they are similar in that they generally contain two or more of the following:

- Hydrocarbons
- Chlorinated solvents (generally methylene chloride)
- Phenolic compounds
- Alcohols, esters, ethers
- Colors, detergents, and odorants

These are powerful solvents and a wide variety of formulations are available especially for removal of different types of paint.

2.2.3 Paint Thinners

Industrial operations involving painting use one or more paint thinners. These materials are formulated specifically for the type of paint used and may contain one or more of the following types of materials:

- Hydrocarbons (Mineral Spirits, naphtha, toluene, xylene, etc.)
- Alcohols (Methanol, Ethanol, Isopropanol, etc.)
- Esters (Ethyl acetate, amyl acetate, etc.)
- Ketones (Methyl ethyl ketone, Methyl isobutyl ketone, etc.)

2.2.4 Halogenated Solvents

Halogenated solvents used include a variety of chlorinated solvents and Freon 113. Several popular chlorinated solvents have been designated as potential carciniogens by EPA and thus the major products still in use are:

- Methylene chloride
- Trichloroethane (TCA)
- Freon 113

Reference has been made above to the use of methylene chloride in cleaners and strippers. This material and TCA are also used to clean electrical parts. Freon 113 and TCA are also used for precision cleaning of bearings. The major benefits of these halogenated solvents are:

- High solvent/cleaning power
- Rapid evaporation rate (low residue)
- Non-flammability

2.3 Other Materials Used

The other major materials used are antifreeze and water based materials. There are two types in general usage

2.3.1 Antifreeze

- Ethylene glycol
- Isopropyl alcohol

Except for very low temperature service ethylene glycol is commonly used. Isopropyl alcohol has very good low temperature properties, but for all year use, it tends to boil off in warmer weather.

2.3.2 Water Based Materials

The major systems used are:

- Detergents
- Alkaline solutions

A wide variety of detergents can be used for cleaning purposes which generally contain phosphates and/or organic compounds. These may be used in conjunction with steam or hot water systems.

Alkaline solutions may contain either sodium hydroxide (caustic soda) or organic amines. These are generally used to dip tanks and must be handled by trained personnel since they can cause severe skin burns and are very toxic.

3. Generation and Properties of Used Oils and Solvents

3.1 Used Oils

"Used Oil", as defined by EPA "is petroleum-derived or synthetic oil including, but not limited to oil which is used as a lubricant, hydraulic fluid, metalworking fluid, insulating fluid or coolant and which is contaminated through use or subsequent management." Used oil varies greatly in its composition, depending on the type of oil, the extent to which it was used, and the intentional or unintentional addition of other wastes to the oil. In this industry, used oils are generated mainly from equipment drainings.

Used oils obviously contain additives originally found in the oils as noted in Section 2.1 and contaminants picked up in use such as:

- Lead (Pb) from leaded fuels and bearings
- Chromium, Manganese, Iron and other metals from wear of engine parts
- Water from combustion and condensation
- Antifreeze and solvents from leaks and intentional or unintentional contamination

Typical used oil compositions are shown in Table 3-1 (1) *

Many used motor oils have low Flash Points due to the presence of unburned gasoline.

RCRA regulations for burning of used oils are given in Table 3-2.

Metalworking fluids frequently contain higher levels of heavy metals and chlorinated compounds than do other industrial oils (including hydraulic, compressor, turbine, and electrical). Many times the metalworking and hydraulic oils contain extreme pressure additives which are chlorinated hydrocarbons. (1)

Hydraulic and transmission oils often have few contaminants. However, hydraulic systems are often flushed out with halogenated solvents and thus the used oils may contain as much as 10 - 30 of TCA or Freon 113.

3.2 Used Solvents

Used solvents may be defined as any used organic fluid contaminated as a result of use for cleaning, thinning, or use as a solvent, antifreeze or similar purpose. Used solvents are generally volatile in nature. They include hydrocarbons, halogenated hydrocarbons, oxygenated hydrocarbons and mixtures of these materials.

Used cleaning solvents are generally produced by spraying, physical or vapor washing, dipping and other means. Used paint thinners are a special case since they are produced by cleaning paint equipment rather than from thinning operations.

Typical properties for used hydrocarbon, TCA and Freon 113 solvents are given in Tables 3-3, 4 and 5 along with properties of virgin or reclaimed solvents. Properties for virgin and reclaimed solvents should be essentially the same and can generally be accomplished with available resources. No properties are given for paint thinners since reclaimed paint thinners should not be used as paint thinner. However, the reclaimed thinners can be used for cleaning paint equipment and no specifications are needed. If it works, OK, but if not, it should be disposed or reformulated if desired.

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* Numbers in parenthesis refer to references given at the end of this paper

Table 3-1

Typical Used Oil Composition

Type Variable	Motor Oil (1) Value	Industrial Oil Value
Gravity, °API	24.6	26 - 35
Viscosity/100° F, Centistokes	53.3	3 - 25
Viscosity/210° F, Centistokes	9.18	—
Flash Point, F	215	160 - 240
Water (by distillation), Vol. %	4.4	0.1 - 0.5
Sulfur, WT %	0.34	0.2 - 1.3
Ash, Sulfated or Sulfonated, WT%	1.18	3 - 5 ppm
Lead, WT%	0.11	—
Calcium, WT%	0.17	—
Zinc, WT%	0.08	—
Phosphorus, WT%	0.09	—
Barium, ppm	568	—
Iron, ppm	356	—
Vanadium, ppm	5	—
Arsenic (As), ppm	—	<0.5
Cadmium, (Cd), ppm	—	<0.2
Chromium, (Cr), ppm	—	<0.5

Table 3-2

RCRA Regulations For Used Oils Burned As Fuels

Variable	Value
Flash Point, F, min	100
Metal Content, ppm maximum	
As	5
Cd	2
Cr	10
Pb	100
Total Halogens, ppm, maximum*	1000 (rebuttable) 4000 (non rebuttable)

---

* If the total halogens are in the range 1000 to 4000 ppm and one can prove that his oil has not been mixed with hazardous waste, then this oil will meet the on-specification criteria.

Table 3-3

Typical Properties of Used, Virgin or Reclaimed Hydrocarbon Cleaning Solvent

		Properties For		
Test	Test Method	Used Solvent	Virgin or Reclaimed Hydrocarbon Solvent	Virgin or Reclaimed High Flash Solvent
Flash Point, TCC,F	ASTM-D-56	<100-140	102-110	140 min
Distillation,F	ASTM-D-86			
IBP		150-330	315-330	355-360
10%		150-340	320-340	360-370
20%		170-340		
30%		300-345		
40%		320-350		
50%		325-350	325-350	365-380
60%		330-370		
70%		340-390		
80%		350-400		
90%		400-600	330-365	375-390
FBP		Above 500	350-400	415 Max
Residue		30 Vol% (Max)	2-5 Vol%	2-5 Vol%
Chlorine Content		<0.1	<0.1	<0.1
Water, Oil & Sediment%	ASTM-D-95	2-20	<0.1	<0.1
Appearance	Visual	Brown/ Black	Clear/ White	Clear/ White

Table 3-4

Typical Properties of Used, Virgin, or Reclaimed TCA Solvent

		Properties For	
	Test Method	Used Solvent	Virgin or Reclaimed Solvent
Flash Point, TCC/F	ASTMD1310	None	None
Distillation, F	ASTMD1078		
IBP		149+	171
50%		190-250	
FBP		500+	190
Residue		10-40%	10 ppm (Max)
Water Content, ppm	16822A	1-5%	100 ppm (Max)
Appearance	Visual	Black	Clear/White
Specific Gravity @ 25 C	ASTMD2111	1.15-1.3	1.317-1.324
Acid Acceptance No. mg NaOH	16822A(*)		0.20 (Min)

(*) Need to check supplier for details of tests to be run and additives required to reformulate reclaimed solvent.

Table 3-5

Typical Properties For Used and Virgin Freon 113

	Test Method	Properties For Used Solvent	 Virgin Solvent
Boiling Point,F	(*)	104+	117.6
Residue	(*)	20% (max)	< 2 ppm
Water Content, ppm	Karl Fisher	1-5%	<10 ppm (Max)
Appearance	Visual	Brown/Black	Clear/White
Specific Gravity @ 25 C	ASTMD2111	1.2-1.565	1.565
Acid Number, mg KOH	(*)	<0.5	0.003 (Max)
Particulate Matter 25-100/100 ml	(*)	100+	100 (Max)

See DuPont Technical Bulletin for details

4. Reclamation Options

4.1 Used Oils

The major options for used oils are on or off-site reclamation. Reclamation can produce oils mainly for the following purposes:

- Fuel use - most used oils end up as components of fuels
- Original use - extending the life of oils and treating for the original purpose are mainly appropriate for turbine and some lube oils
- Downgraded use - some synthetic oils, if properly segregated, can be used as plasticizers

4.2 Used Solvents

Both on and off site options are available for solvent reclamation. The major options are:

- Distillation on site - this is appropriate for most solvents except carbon and paint strippers provided the economics can be justified.
- Off site toll recycling - outside contractors will reclaim and return solvents to the user for a service (toll) charge). This is generally limited to hydrocarbon solvents and carbon removers. However, these services are not universally available.
- Off site recycling - outside contractors will buy or accept many but not all solvents for reclamation. Generally only large volume generators can be serviced.

4.3 Other Materials

Antifreeze - some industrial concerns are starting to accept antifreeze and this material is dewatered and burned as fuel.

Aqueous emulsions - high water content emulsions need to be treated to separate out the oils and grease. The clean water can be discharged to a sewer (where permitted) and the oil and grease disposed.

Caustics - these materials should be neutralized carefully and treated in an industrial wastewater treatment plant.

Further details and examples of hazardous waste reduction in management of used oils and solvents are given in the next section.

5. Hazardous Waste Reduction Practices and Examples

5.1 Audits

Any waste reduction program should start with an audit. This can be a do-it-yourself activity or larger facilities may wish to hire an outside consultant. A standard format is given in Table 5-1 (2). As can to been from the complexity of the audit form the information needed to do a thorough job can be extensive. However, in many cases it is quite simple, but it is essential to know what is being used, how it is used and how are the waste managed.

The benefits of an audit are as follows:

- It requires thought and consideration of current practices
- Materials are identified by chemical types and properties
- Evaluation should reveal opportunities for improvement
- Regulatory deficiencies should be identified
- Corrective actions can be initiated

Table 5-1
Standard Waste Audit Format - Automotive Repairs (2)

- Name and location of shop or business
- Name of Audit Personnel
- Date of Audit
- Type of Shop
  - Automotive repair
  - New car dealer
  - Diesel repair
  - Transmission repair
  - Brake/Muffler shop
  - Radiator service
  - Alignment
  - Suspension/chassis
  - Scheduled maintenance
  - Quick lube changes
  - Body/Painting
- Size of shop
  - Vehicles serviced per week
  - Number of service bays available
- Services Provided
- Number of Employees
- Raw Materials Used

Item	Raw Material	Descrip.	Hazard Clan	ID No.	Density lb/gal	Quantity		Storage Fac. gals.
						Used gals/mo	Disposed gals/mo	
Ex 1 etc.	Parts Cleaning Solvent	Petroleum Solvent BP 310-3470F	Combustible Liquid		7	50	50	250

- Raw Material Storage (Complete for each item)
  - Raw material (Brand name/common name)
  - Item No.
  - Volume in Inventory
  - Describe usage
  - Describe disposal practice
  - Describe storage facilities

ie. 55 gal drum
Containers (Volume)
Above or underground tank
Covered/open
Indoor/outdoor
Secured

Table 5-1 - continued

- Delivery system
  - ie. Gravity
    - Funnel
    - Pump

- Material Control Practices
  - ie. Stockroom attendant
    - Access (Limited/Unlimited)
    - Signout sheet

- o Material Usage (Describe for each type)
  - Sink (Size/description/location)
  - Dip Tank (size/description/location)
  - Jet spray (size/description/location)
  - Spray hood (size/description/location)

- o Waste Material Management
  - Segregation practiced (Describe, if yes)
  - If no segregation describe practice
  - What options are available for segregation
  - Storage facilities (describe)
  - Disposal practices
    - ie. On-site recycling
      - Serviced by Equipment Leasee/Maintenance Contractor
      - Picked up by contractor
      - Disposed in Municipal Solid Waste
      - Disposed to Municipal Sewer
  - Disposal Costs
    - Oils
    - Solvents
    - Residues/Sludges
    - Antifreeze
    - Aqueous materials
    - Others

- o Material Losses
- o Provide a Schematic for Waste Management Practices
- o Prioritized Sites of Significant Waste Generation
- o Waste Management Options
- o Source Reduction Options

  - Material substitutions
  - Process changes
  - Housekeeping

- o Regulatory Compliance Evaluation and Needs
- o Recommendations for Improved Management

5.2 Identifications of Options

Once the audit has been completed, it is necessary to consider what options for waste management are appropriate. The major areas for consideration are noted below.

5.2.1 Material Selection

Can other material be found that will reduce the volume and management problems?

Example - For the Navy, a Flash Point minimum of 140 F is essential for reclamation as a fuel. By changing from low to high flash cleaning solvent, the used solvent could be blended with used oils and burned in their powerhouse. Recycling this solvent was not practical because of the low volumes and no off-site services were available.

Example - A large repair shop switched from TCA to High Flash Petroleum solvent because of a concern about the toxicity of TCA. Those operations involving mechanical equipment favored the change because of the oily film left on cleaned parts. By contrast, those involving electrical equipment did not like the change because of the oily residue.

Example - A shop using TCE was convinced by a supplier to change to a reportedly safer hydrocarbon solvent. The material provided was an odorless paint thinner which did not have the desired solvent power.

Example - Users of hydrocarbon cleaning solvents are convinced to switch to detergent formulations for cleaning all types of mechanical and electrical parts. While the cleaners may perform satisfactorily, the used aqueous mixture may or may not be legally disposed to the sewer.

Example - Hydrocarbon cleaning solvent is used to clean high precision bearings. There used product can then be distributed to less critical parts cleaning operations.

5.2.2 Segregation

Segregation is probably the single most important and readily manageable practice which can have a major impact on hazardous waste reduction. Past practices generally have not mandated segregation so all of us dump into the nearest waste container and let the disposer handle the wastes. Segregation is essential to not only proper but any kind of management of all types of wastes.

Segregation into various types of used oils and solvents is a must to reduce both costs and problems. Grouping by the following types of materials can be useful.

- o Oils for Fuel Use

This group contains all used oils and solvents with a Flash Point above 140 F. No halogenated materials are allowed

- Individual Solvents and Oils

Each solvent should be kept separate to optimize the potential for recycling whenever possible. In cases where disposal options and costs are not affected by composition, segregation may not be appropriate.

Some oils, especially synthetic lube and fire safe hydraulic oils, if segregated can be sold for recycling or reuse as plasticizers.

- Low Flash Materials and Mixtures with Halogenated Solvents

Materials with a Flash Point below 100°F and mixtures with halogenated solvents, especially low volumes are difficult to recycle and dispose. Generally the generator will have to either avoid these materials or pay the costs for disposal.

Example - Many automotive shops dispose of solvents and oils in a common receptacle. The practice generally increases disposal costs. Segregation is mandated in many areas, but is dependant upon local options.

5.2.3 Recycling

5.2.3.1 Oils

As noted in Section 4.1, recycling of used oils is generally limited to the following:

- Fuel Use
- Extended life and Lube Oil Recycling
- Downgrading

Examples of Fuel Usage

- Many large industrial operators segregate and collect used oils for in-house fuel use
- Small generators are usually limited to segregation and disposal to collectors who blend used oils for fuel use. Costs vary from no charge to $0.25/gal for disposal
- Small used oil burners are available for on site recycling
- Mixtures of fuels, solvents and some chlorinated solvents can be disposed for use as fuel for asphalt and cement kilns. Some limits are generally placed on their composition.

Examples of Extended Life and Lube Oil Recycling

- Used oils from various sources can be processed to extend their useful life. This is not common practice for engine lube oils. Some hydraulic and many turbine lube oil users have in-house systems to treat oils. These systems remove volatiles (water and low boiling hydrocarbons) and solids to clean up the oils for reuse.
- Lube oil recycling has fluctuated with the price of oil. Recyclers can handle most engine and industrial oils. Processing generally involves the following steps:

1. Settling to remove water and solids
2. Fractional distillation to separate low boiling fractions
3. Vacuum distillation to produce lube oil base stocks
4. Treatment of the lube oil fractions (Clay or hydrogen treatment)

The lower boiling fractions are generally used on site for fuel and higher boiling fractions blended into #2 Fuel Oil. Lube oil fractions, after treatment, are sold for reformulation.

Examples of Downgrading

Used fire safe hydraulic oils can be sold. Recyclers will take a minimum of 4-6 drum lots containing less than about 2-4% petroleum oils for reprocessing and sales as plasticizer.

5.2.3.2 Solvents

Options were noted in Section 4.2 and include on and off site recycling. On-site options require purchase of simple equipment to recycle segregated solvents. Off-site options include toll recyclers and reprocessors.

- On-site Recycling

Numerous suppliers provide equipment for recycling of almost all solvents. The equipment does not provide fractionation or separation of solvents. Equipment sizes range from 5 - 500 gals/day and costs range from $2 - 3,000 on up. There are two major types of equipment.

- Externally heated vessels with or without vacuum attachments for high boiling solvents
- Steam injection units where live stream is injected into the solvent and both are distilled and condensed. This is appropriate only for water immiscible solvents.

Examples

- A road asphalt supplier used a 5 gal/day still to recycle chlorinated solvents from laboratory testing operations. This is done to minimize disposal problems.
- Many firms have in-house solvent stills to recycle solvents such as:
  - Shipyards - hydrocarbons, Freons, paints
  - Machine shops - hydrocarbons, TCA
  - Electrical motor rebuilders - TCA
  - Ink manufacturers - organic chemicals, etc.
- Hydraulic shops use a stream injection unit to remove TCA from hydraulic oils. The TCA and oils are recycled.

- Off-site Recycling

Many solvent recyclers are available to handle relatively large generators of solvents. The National Association of Solvent Recyclers lists 15-20 major companies in the eastern US. These firms service a radius of up to about 500 miles.

Toll recyclers provide service to both small and large industries. One example is Safety-Kleen, others also provide this type service. Toll recyclers rent the equipment and solvent, when it is dirty the solvent is replaced and the unit serviced (filter cleaned or replaced). They charge for this service, but it relieves industries from handling wastes. A major problem of toll recyclers is that their services are generally limited to petroleum hydrocarbon cleaning solvents and carburator cleaners. Paint and halogenated solvents are not generally accepted. However, this may change as the industry sees the need.

6. Conclusions

Management of used oils and solvents is becoming more of a necessity and burden to all. However, it is necessary to protect our environment especially our water resources. Indescriminant disposal of wastes can no longer be tolerated. All oils and solvents encountered in visits to hundreds of shops in this country and overseas have been found to be recyclable. The economics and best management practices need to be evaluated generally on a site-by-site basis in order to select the optimum system. In many locations solvent recycling equipment can be paid off in 2-10 years depending upon the volumes and costs of the solvents. At major oil generating facilities, savings have amounted to hundreds of thousands of dollars per year.

References

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Waste Minimization Program at Union Carbide

by
Ronald Burstein, P.E., CHMM
Staff Environmental Engineer
Union Carbide Corporation
Bound Brook, New Jersey

(Originally Presented at CMA Seminar - November 1987)

WASTE MINIMIZATION PROGRAM

UNION CARBIDE - BOUND BROOK PLANT

The Union Carbide Corporation site located in Piscataway, New Jersey, produces specialty polymers. The site also hosts a major technical center consisting of various R&D laboratories and pilot plants. The site currently has approximately 1200 employees. Due to the diverse nature of the site's operations, developing and implementing an effective waste minimization plan has been a challenge. This presentation will focus on the development of the waste minimization plan.

As with most plants, the Bound Brook site implemented many waste minimization projects over the years. As examples, during the 70's and early 80's, the plant began using waste streams as boiler fuel, installed an incinerator and implemented recovery operations for stillwashes. With the passage of the 1984 RCRA amendments, the plant formalized its waste minimization efforts and implemented the formal corporate-wide program. Various projects were under consideration in 1986 when the plant focused on hazardous waste disposal costs. The 1987 budget process highlighted the dramatic increase in hazardous waste disposal costs (up over 200%) since 1983 even though the plant was generating significantly less waste in 1987. Plant management challenged the Environmental Protection Department to develop a comprehensive waste minimization program to identity reduction potentials. The steering team and unit audit teams were formed, audits were conducted and numerous projects were identified. The expected benefits (over a two-year period) include an overall waste reduction of approximately 50% and hazardous waste disposal cost reductions of approximately 25% to 30%. The presentation will focus on the various steps of the process (Formation of Steering Committee, Formation of Unit Teams, Conducting the Audit, Audit Reporting, Evaluation Process, Tracking System and Follow-up).

In addition to the RCRA waste minimization requirement, the State of New Jersey and the local county courts recently adopted more encompassing recycling requirements. The presentation will briefly discuss this development and the impact on the site.

BACKGROUND: HISTORICAL ACTIVITIES

1972/1973 - USE WASTES AS BOILER FUEL

1975 - ELIMINATE HAZARDOUS WASTE LANDFILLING OF LIQUIDS

1976 - INSTALL HW INCINERATOR (R&D)

1978 - USE "SECURE" HW LANDFILLS FOR SOLIDS

1983 - BOILER FUEL "BUBBLE" APPROVED BY NJDEP (NOT IMPLEMENTED)

1983 - RESIDUE PROJECT TEAM (UTILIZED "WASTE MINIMIZATION DISPOSAL HIERARCHY)

1984 - USE HDPE DRUMS FOR HW (REDUCE "METALS")

1985 - "TOLL RECOVER" STILLWASHES

1987 BUDGET

- "STRAW BREAKING THE CAMEL'S BACK"

EP BUDGET (SITE) = $1,600,000

WATER POLLUTION = $500,000
SOLID WASTE (NONHAZARDOUS) = $400,000
CHEMICAL WASTE (HAZARDOUS) = $700,000

- CHEMICAL WASTE COSTS (ABOVE) JUMP 200% SINCE 1983.

WASTE MINIMIZATION AUDIT PROGRAM - 1987

GOALS:

1. REDUCE EP WASTE-GENERATING BUDGETS BY $100,000, (1987 DOLLARS), AND

2. PROVIDE STAFF SUPPORT TO OPERATING AREAS TO REDUCE THE QUANTITY AND/OR TOXICITY OF WASTES AND ASSOCIATED COSTS.

HOW:

1. ESTABLISH HIGH VISIBILITY AND CREDIBILITY BY CREATING WASTE MINIMIZATION AUDIT TEAMS.

2. CONDUCT AUDITS OF ALL OPERATING AREAS INCLUDING R&D, REVIEWING METHODS/PRACTICES CREATING WASTES.

3. INCLUDE THE GENERATION AND REDUCTION OF WATER POLLUTION, SOLID WASTE, AND CHEMICAL WASTE.

WHAT TO DO:

1. CONDUCT ALL AUDITS (7) WITHIN 3 MONTHS.

   NOTE: TENTATIVE AUDIT SCHEDULE TO BE ISSUED WITHIN ONE MONTH FOLLOWING KICK-OFF MEETING.

2. INVESTIGATE SOLID WASTE RECYCLING, I.E., PAPER, CARDBOARD, PLASTICS, GLASS, ETC.

3. INVESTIGATE ON-SITE WASTE BURNING.

4. INVESTIGATE RAW MATERIAL USAGE PRACTICES AND DISPOSITION, I.E., RETURN TO SELLER, USE LESS HAZARDOUS MATERIAL, MAINTAIN LESS INVENTORY.

ORGANIZATION:

1. SITE EP ENGINEER; CHAIRMAN; EXPERIENCE IN ALL AREAS OF SITE.

2. ENGINEERING MANAGER; DEPARTMENT HEAD REPRESENTATIVE (CAN COMMUNICATE TO DEPARTMENT HEAD GROUP), AND DELEGATE WORK ACTIVITY (PROJECT FEASIBILITY) WITHIN ENGINEERING); EXTENSIVE PRODUCTION BACKGROUND.

3. SUPERVISORY (SHIFT) ORGANIZATION; EXTENSIVE PRODUCTION EXPERIENCE.

4. EP REPRESENTATIVE FROM LARGEST OPERATING DEPARTMENT; EXTENSIVE PRODUCTION AND R&D BACKGROUND.

5. EP COORDINATOR AND/OR DAY COORDINATOR OF AUDITED DEPT; ASSIST TEAM IN REVIEWING SPECIFIC DEPARTMENT'S OPERATION; MUST BE WELL VERSED IN WASTE-GENERATING PRACTICES.

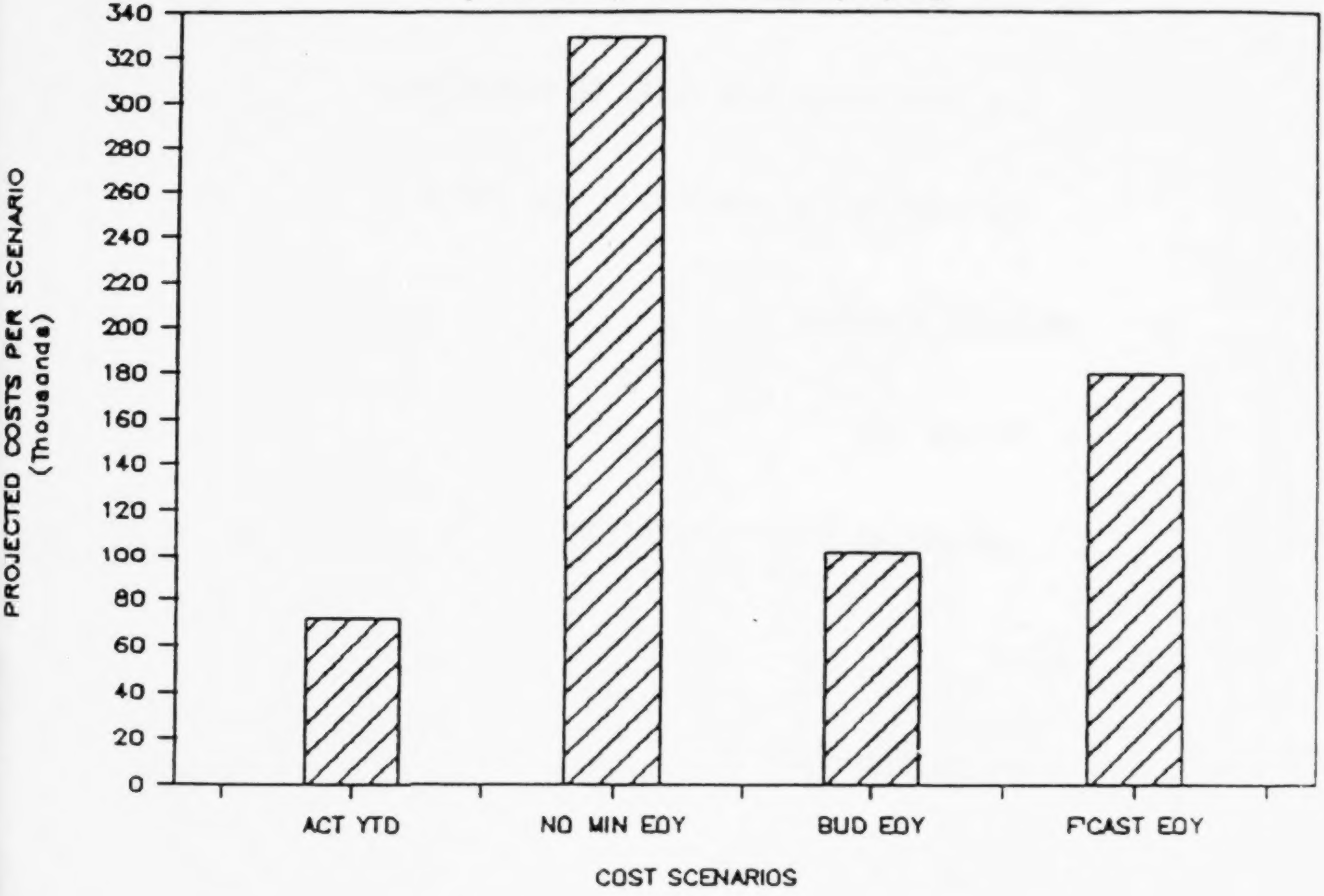
WHAT TO DO:

5. ISSUE REPORTS FOR EACH AUDIT AFTER U/A WITH RESPONSIBLE MANAGER, DELINEATING RECOMMENDED WASTE REDUCTION PROGRAMS AND THEIR POTENTIAL COST AVOIDANCES.

6. ONCE AUDITS ARE PERFORMED, ISSUE QUARTERLY "TRACKING REPORTS" COMPARING BUDGETED VERSUS ACTUAL WASTE COSTS AND QUANTITIES FOR DEPARTMENTS, PLANT AND SITE. ISSUE "TRACKING REPORTS" FOR SPECIFIC RECOMMENDED PROJECTS, I.E., CAPITAL AND EXPENSE.

1987 CHEMICAL WASTE DISPOSAL:PHENOLICS

(includes disposal costs thru 6/30/87)



AUDIT PROCEEDINGS

I. DEVELOP UNIT BASELINE

- USE 1986 GENERATION RATE; DO GENERICALLY.

- USE 1987 ACTUAL WASTE COST PER STREAM

II. PREAUDIT PLANNING

- REVIEW (I)

- UNDERSTAND WASTE GENERATION

III. AUDIT

- PRIORITIZE FROM (II)

- VERBALIZE FINDINGS

IV. POST AUDIT REVIEW OF DRAFT REPORT

V. DEPARTMENT HEAD REVIEW & ACCEPTANCE

VI. ISSUE REPORT

VII. ACTION PLAN AND FOLLOW-UP

FINDINGS

NOTE: FULL IMPLEMENATION COULD TAKE TWO-THREE YEARS

DEPARTMENT	MAXIMUM POTENTIAL WASTE REDUCTION	MAXIMUM POTENTIAL COST REDUCTION (87$'S)
STAFF A	65%	$20,000
PRODUCTION A	70%	$400,000
STAFF B	40%	$15,000
PRODUCTION B	75%	$170,000
STAFF C	60%	$1,500
PRODUCTION C	55%	$100,000
RESEARCH & DEVELOPMENT	55%	$125,000
TOTAL	60%	$800,000+

BOUND BROOK SITE

RECYCLING PROGRAM/CHARTER

OBJECTIVE:

IMPLEMENT RECYCLING PROGRAM FOR BOUND BROOK SITE - FOR HIGH-GRADE PAPER, ALUMINUM CANS, GLASS, NEWSPAPERS/MAGAZINES, AND CORRUGATED CARDBOARD - BY AUGUST 1, 1987 (BEGAN JUNE 23RD).

KEY TASKS:

- IDENTIFY QUANTITY AND COMPOSITION OF RECYCLABLE SOLID WASTES (NEED TO ASSESS THE POTENTIAL RECYCLABILITY OF ALL STREAMS)
- EVALUATE THE LOGISTICS FOR RECYCLING
- ASSESS/ASSURE MARKETS FOR RECYCLABLES
- IMPLEMENT PROGRAM

TEAM COMPOSITION:

STEERING COMMITTEE

- SITE EP ENGINEER, TEAM LEADER
- WASTE MINIMIZATION AUDIT TEAM
- R&D MAINTENANCE DEPARTMENT HEAD
- PURCHASING/MATERIALS MANAGEMENT REPRESENTATIVE

WORKING COMMITTEE (UTILIZE SOME SUPERVISORY AND WAGE PERSONNEL)

- ONE ADDITIONAL R&D REPRESENTATIVE
- OPERATING/STAFF DEPARTMENT REPRESENTATIVES (WASTE MINIMIZATION REPRESENTATIVES) AND
- CONSULTANT (AD HOC MEMBER) (CRITICAL)

PROGRAM

- SOURCE SEPARATION (BY AREA, BUILDING, FLOOR):
  - OFFICE PAPER
  - CORRUGATED CARDBOARD
  - COMPUTER PAPER
  - ALUMINUM CANS
  - GLASS
- USE EXISTING SOLID WASTE EQUIPMENT.
- CONTAINERIZATION OF RECYCLABLES.
- MANPOWER AND LOGISTICS FOR COLLECTION/PICK-UPS.
- PUBLICITY.

RESULTS

- ANNUAL COST AVOIDANCE (1987 DOLLARS) OF $120,000!

- OTHERS:
    - DECREASED USAGE OF GARBAGE CONTRACTOR.
    - DECREASED USAGE OF JANITORS.
    - INCREASED EMPLOYEE MORALE.

Union Carbide's Emission Reduction Program

Presented by
Gary M. Whipple
Assistant Director
Chemicals and Plastics Environmental Affairs
Union Carbide Corporation
Danbury, Connecticut

UNION CARBIDE'S EMISSION REDUCTION PROGRAM

by

Gary M.Whipple
Chemicals and Plastics Environmental Affairs
Union Carbide Corporation

Introduction:

Today, I would like to share the results of Union Carbide Chemicals and Plastics' Emission Reduction Program with you. This program was conceived to restore confidence in Union Carbide following the Bhopal tragedy and a release at Institute. The program is designed to achieve a thirty percent reduction in continuous emissions for each of three years, and a thirty percent reduction in episodic releases for each of three years. Union Carbide dedicated $100MM of capital, over and above normal expense and capital programs, to achieve these goals. The work described herein started in September of 1985, and is expected to continue for at least another eighteen months.

As you'd expect, it took considerable time and effort to translate these goals into a workable program, and to identify the projects that would maximize emissions reduction and reduce potential episodic releases. I would like to present an overview of the process used to determine which projects to fund, and the results of the program to date.

Discussion:

Program

We were helped considerably in our efforts by the discussions that led to the development of the CMA Air Toxics Policy. Union Carbide's policy is similar to CMA's and was established at about the same time. Union Carbide's Air Toxic Policy provided a framework that helped move the program forward. It requires:

- Accurate, annual air emissions inventories
- Identification of possible accidental release scenarios
- Assessment of the impact of releases
- Corrective actions where appropriate

Having an accurate emissions inventory and a corporate policy helped to focus first on preventing episodic events that could affect the community or pose health and safety risks to our employees. The emissions inventory also helped us establish priorities that put potentially toxic air pollutants ahead of volatile organic emissions. As part of our SARA Title III reporting, we are developing an online environmental database that will make it easy and convenient to update our emissions inventory each year.

Very early in the process, we understood the need to treat routine, continuous emissions differently from abnormal, episodic emissions. In the case of continuous emissions, we were striving for reductions of pounds of air pollutants. In the case of episodic emissions, however, we were trying to reduce both the number of pounds emitted and the probability of a release. With episodic emissions, the primary goal is prevention by reducing the chances of an occurrence; however, the need for mitigation of a potential event was also considered.

Continuous Emissions

We began the Continuous Emissions Program by focusing on routine, continuous emissions such as point sources, secondary emissions, fugitive emissions, and startups and shutdowns. To help direct efforts to sources of hazardous air pollutants, we devised a new index, called an AAPU, or Adjusted Air Pollutant Unit:

$$\text{AAPU} = \frac{\text{Mass Emitted (tons/year)}}{\text{TLV (mg/m}^3\text{)}}$$

This new index helped us keep score, and ultimately was one of the ways we set spending priorities to make the most effective use of our funds. As we look at Figure......, you can see that the AAPU index focused attention on materials like ethylene oxide, rather than bulk solvents.

Once we had an inventory of all of our continuous emissions, we set out to determine which had the most significant impact on the surrounding communities . First, we eliminated any emissions which fell below predetermined de minimus values based on consideration of a chemical's toxicity:

TLV, mg/m^3	Deminimus Emission Rate,lb/hr
< 5	1.0
6-12	1.5
13-25	3.0
26-50	7.1
51-250	13.0
251-500	65.0
> 500	130.0

We subjected all continuous emissions that exceeded the deminimus values to a second level screen, which was a simplified dispersion model:

$$C = 32\ Q\ h^{-1.93}$$

where Q=emission rate,lb/hr
h=stack height
C=concentration,mg/m^3

Where the maximum concentration ocurred inside the fenceline, the following equation was used to estimate fenceline concentration:

$$Cp = C\ (10h/Xp)^{1.6}$$

where Cp = Concentration at the fenceline
C = Maximum ground level concentration
Xp = Distance to fenceline

If a source failed this second level screen, we re-examined the data for accuracy, and considered more refined modeling and/or controls. Failing the screen meant the concentration at the fenceline or beyond exceeded one percent of the TLV or an AEG (Air Exposure Guideline). Other criteria, like flammability, proximity of population, odor, etc. were also considered when it was appropriate. Since the second level screening model assumed worst-case meteorological conditions, the modeling was extremely conservative and resulted in a number of failures. Of the 1152 continuous emissions first identified, 675, or 58%, were eliminated by the de minimus criteria from further consideration. The second level screen reduced the number further to a total of 84 sources for final action.

Episodic Emissions

We followed a parallel screening effort for episodic emissions like spills, tank ruptures, relief valve discharges, and rupture disk discharges. Once again, we began with an inventory of possible releases. We defined episodic emissions as those which result from sudden, accidental releases which are abnormal and unplanned. In this case, we included releases to the water and land as well as to the air, while the continuous emissions effort was limited to air. We included in our criteria the maximum amount of material that could be released if the release occurred. Reportable episodic releases met the criteria:

- a release reported to a government agency

- a release which caused an injury
- a release which impacted the community or which they were aware of
- a release which was the subject of media inquiry
- a release of 5000 pounds or more of process material, waste, or product

Episodes are routinely reported to Division and Group management as they occur, much as CERCLA or SARA releases are reported to government agencies. Monthly reports summarize the episodes for wide distribution.

We started with a total of 7927 possible episodic releases. A check against the criteria above reduced the number to 3467 potentially significant episodic emissions. We then developed a nomograph for a quick check on the impact of these episodic emissions; the nomograph eliminated another 2467 sources from consideration. This nomograph treated all episodes as though the material was released over both a 2 minute and a 10 minute period, and then instantaneously released at ground level. Finally, either a generic spill screening model (for ground level releases) or a elevated source screening model (for most of the relief valves) reduced the list of sources to 300 which needed a refined analysis. The elevated source screening model was a Gaussian model that calculated maximum ground level concentrations at the fenceline or beyond under the worst case combination of wind speed and stability. A protocol was included to select plume rise (or fall) category based on apparent initial plume density and discharge orientation. The refined analysis involved evaluations on a scenario by scenario basis using the best available tools, including evaporation and flashing models, dense jet and dense plume models where appropriate. Finally, all the remaining "failures" were ranked according to the percentage of criteria met. In the case of episodic emissions, further action, including more analysis or corrective action was required for all those sources we exceeded 10% of the IDLH.

Results:

The program has so far been successful by several criteria. We exceeded the 30 per cent reduction per year in continuous emissions that were set as a goal, acheiving a 36 percent reduction by the end of 1986, and another 27 per cent reduction forecast by the end of 1987.

With respect to episodes, we have reduced the number of reportables from 361 in 1985 to 248 in 1986, and based on the year to date, we should be down to 173 by the end of 1987......an almost exactly 30 percent reduction in each year.

Union Carbide has committed or planned expenditures for the program of $70MM through the end of 1989. We have 194 projects planned and funded; 13 percent of the projects are for episodic incident reduction, 24 percent are for continuous emissions reduction, and 63 percent are for reducing the probability of an episode.

Minimization of Hazardous Wastewater by Process Design

Presented by
James B. Dunson, Jr.
Principal Consultant
Chemical & Environmental Engineering
E. I. Dupont De Nemours & Co., Inc.
Newark, Delaware

MINIMIZATION OF HAZARDOUS WASTEWATER BY PROCESS DESIGN

JAMES B. DUNSON, JR.
PRINCIPAL CONSULTANT
CHEMICAL & ENVIRONMENTAL ENGINEERING
E. I. DUPONT DE NEMOURS & CO., INC.
P. O. BOX 6090, NEWARK, DE 19714-6090

ABSTRACT

This paper describes how new developments in the science of aqueous systems can be utilized to develop chemical process modifications which minimize the emission of hazardous aqueous waste into the environment. It illustrates how the thermodynamics of aqueous systems, and their interactions in the formation of particulates, can have a profound effect on the volume and character of hazardous waste requiring treatment. Examples based on DuPont experience show how these effects can be utilized to effect the desired minimization.

SCOPE

The term "hazardous waste" is often applied to large volumes of inert material such as water or soil which are contaminated with a genuinely hazardous chemical component. It can be safer and cheaper to change the chemical process plant design to minimize the original emission of the hazardous component than it is to provide individualized decontamination after dilution into the inert environment. With the recent emphasis of the chemical process industry on petrochemical syntheses and separations, the technology for dealing with chemicals in water solution has become unfamiliar to most chemical engineers. This paper gives case histories illustrating successful adaptations of classical aqueous chemical process technology to minimize emissions of potentially hazardous modern wastes. Ten different unit operations of chemical process technology are represented:

Separate hazardous component from water:	Separate water from hazardous component:
Crystallization	Azeotropic distillation
Filtration	Waste acid incineration
Adsorption	Dry scrubbing
Ion exchange	Spray drying
Permeation	Sludge incineration

CONCLUSIONS AND SIGNIFICANCE

Contamination of streams, soil, and groundwater with recognizable chemicals has reached a point where society demands that the manufacturing, use, and disposal of potentially hazardous chemicals be accomplished without environmental damage. Aqueous chemical process engineering tends to involve multi-component multi-phase systems with complex thermodynamics which have been difficult even to model mathematically, let alone to isolate for the purpose of getting good reproducible design data. Particle technologists are beginning to understand the entropies and free energies of ions in solution and in surfaces. It now is possible to plot equilibrium phase boundaries based on ion partitioning between the dissolved and the precipitated state, and to measure the kinetics of separations based on real supersaturations.

The message of this paper is that it is possible to use the science of aqueous systems to develop chemical engineering process modifications which really do minimize emissions of wastewater contaminated with hazardous chemicals. Other papers presented here have also discussed ways of minimizing the generation of hazardous waste in order to decrease the possibility of environmental contamination. This meeting represents a welcome opportunity to compare waste minimization experiences with our colleagues in various industries.

Hazardous Components of Waste

The chemical process industry manufactures a wide variety of synthetic materials which make it possible for people to feed, clothe, house, transport, employ, and entertain each other with less work than would be required using naturally available materials. We take it for granted that in the processing of natural materials there are particular components which we want to use, while other components are inappropriate for the immediate purpose. The useful components we call raw materials and the others we call wastes. The same situation applies in the chemical process industry. Chemical plants start with stable natural minerals such as coal, petroleum, limestone, salt, and sulfur. These are taken apart and reacted with air and water to form both the desired useful materials, and byproduct waste materials for which no significant use is presently available.

"Hazardous waste" is a technical description which is often misused by nontechnical enthusiasts. A distinction needs to made between ordinary waste, which can be handled along with regular municipal waste, and special waste, which requires different handling for safe decontamination. The description "hazardous waste" should be reserved for those particular special components which are so difficult to decontaminate that they must be processed individually and appropriately to assure complete decontamination.

Figure 1 shows some examples of typical liquid wastes which may be hazardous due to the presence in low concentrations of genuinely hazardous components. One of the most effective ways of minimizing the generation of hazardous waste is to change chemical processes so as to avoid diluting toxic substances with inerts such as water. This paper will explore the subject of changing chemical process design to minimize the emission of potentially hazardous aqueous wastes into land disposal or wastewater treatment plants.

DuPont had a company-wide symposium on waste minimization last year in which examples of waste minimization were highlighted by more than 60 different speakers. Figure 2 shows those engineering technologies which I have chosen to highlight today as examples of waste minimization. I have personally been involved in one way or another with all of these. You will notice that none of these are "classical" chemical engineering in the sense of petrochemical separations, where equipment can be designed by standardized computer programs with little need for experienced consultants. All of these technologies are still emerging into chemical engineering science. It is precisely in these frontier areas that many of the opportunities lie which keep the practice of chemical engineering in the sunrise rather than the twilight zone of the marketplace.

Crystallization

Crystallization is a good example of one of our old technologies which is being revitalized as a result of improving techniques for measuring the characteristics of ions in solutions and of fine particles in suspensions. What actually happens is still very much under the control of the kinetics of several things happening in series, some of which are typically very fast and some very slow. A solution ready to crystallize can be supersaturated with respect to several different species at once, and can be encouraged to grow the desired product by seeding with a small amount of it. The rate of that growth is also important. In order to control the particle size distribution, you must control the rate of development of supersaturation to match the crystal growth rate so that a relatively moderate number of larger "templated" crystals are produced by precipitation on the seed compared to a relatively enormous number of tiny uncontrolled crystals.

We typically find it helpful to design crystallizers with large gentle recirculations of crystals between zones which are slightly undersaturated and others which are appropriately supersaturated. That way any fines which do form have an opportunity to redissolve and reprecipitate on the larger crystals, which are inherently slightly less soluble. With modern on-line particle characterization equipment, it is then possible to control crystallizers to maintain a steady-state particle size distribution.

There are several interesting examples of using crystallization for waste minimization. The neutralization of weak waste sulfuric acid is one of the classical waste disposal problems. The uncontrolled mixing of lagooned waste acid with lime results in the formation of a heavy gelatinous slime which cannot be filtered and does not settle or dry out. I have seen slime pits fifty years old which are still the consistency of quicksand. The controlled neutralization of dilute sulfuric acid with lime or limestone in properly designed crystallizers, on the other hand, can produce coarsely crystalline gypsum which will drain dry on a concrete pad and can be used to make normal quality gypsum wallboard or low density aggregate. The water which was formerly tied up with the slime can be discharged or recycled; it's analysis is normal for good quality hard groundwater.

A related classical waste disposal problem is the neutralization of spent pickling liquor from metal processing. Acid drainage from coal mines has almost exactly the same chemistry and disposal problem, but is typically more dilute than pickle liquor. They are not only highly acidic like the waste acid just discussed, but in addition also have a tremendous oxygen demand due to dissolved metals in low valence states. Uncontrolled neutralization again produces pits full of even more troublesome slime with high potential for contaminating underlying ground water with toxic metals.

The controlled neutralization of pickle liquor or mine drainage requires choosing conditions such that not only crystalline gypsum but also crystalline magnetite are the thermodynamically stable species. That normally requires oxidizing the iron with air at a controlled rate while simultaneously maintaining the temperature and pH at such levels that anhydrous magnetic iron oxide is the thermodynamically preferred species which gradually crystallizes out in particles which are a convenient size for recovery by magnetic separators. The recovered magnetite paste is well suited to blending with iron ore fines and coke breeze to produce briquettes for recycle to a blast furnace.

The temperature required to obtain recoverable anhydrous magnetite happens to be higher than the range where gypsum is the least soluble form of calcium sulfate, but by starting the crystallizer up with an initial charge of gypsum formed by neutralization of sulfuric acid at lower temperature, it will continue to form gypsum by templating even at the higher temperature required for magnetite precipitation. Recovered gypsum contains surprisingly little iron oxide and is well suited for lightweight aggregate.

There are other situations in which anhydrous crystalline magnetite is not the appropriate precipitate. One highly effective way of removing many dyes and other polar organics from synthesis or dyeworks washwater is by precipitation of an insoluble "lake pigment" with a hydrated metal oxide floc of the opposite charge. Four different feed materials may typically be used, each of which both precipitates and changes the charge polarity of its precipitate at characteristic pH values determined by its thermodyamic stability diagram.

Sodium silicate, aluminum sulfate, ferric chloride, or potassium permanganate can all be used to generate charged flocs which are appropriate for removing polar materials which would normally pass through primary treatment to contaminate biosludge and require expensive tertiary treatment with activated carbon. Ferric chloride is a particularly apt water treating agent, since it is generally a non-prime product from steel or titanium dioxide plants.

Filtration

It is appropriate while discussing primary sludge to move on from the subject of crystallization to the subject of filtration. Filtration of primary wastewater treatment sludge to reasonably high percent solids for disposal is one of the classical chemical engineering challenges. It can be done successfully provided that careful attention is paid to the fundamentals controlling fluid flow through a porous medium.

From the beginning it must be recognized that filtration in general is by the accumulated filter cake rather than the fabric filter support medium. It is important that the medium be economical, durable, and capable of forming a good filter cake quickly. Beyond that point all the action is in the filter cake. It is important that it contain a range of particle sizes, especially some relatively larger and stronger particles to serve as a porous matrix through which fluid can flow and within the pores of which the smaller particles can collect without seriously obstructing flow. It is helpful when the environment is strongly ionic so as to minimize the degree of hydration of the finer particles and therefore permit forming a dryer cake.

Lime is typically used as a primary treating agent for wastewater. It is well suited for that purpose since it generally does not dissolve completely, but tends to dissolve with precipitation of solids like calcium sulfate or hydrated iron oxide as a skin on the residual kernal of lime. Permeability of the resulting filter cake is much better than it would be without the matrix of lime kernals. Dewatered primary sludge is ordinarily disposed of to a landfill; where it contains high concentrations of lime or of organics it can be appropriate to incinerate it, as will be discussed later.

Another type of filtration which can be appropriate for waste minimization is the polishing removal of fine suspended solids by filtration through a deep bed of fine fibers or granular solids. That is similar to the treatment of potable water, where water after primary treatment to remove suspended solids is filtered through beds of sand to remove all remaining solids including bacteria. The difference in using deepbed filtration for waste minimization is that typically the flows are small, the solids are sticky, the filtrate is to be recycled, and the filter medium cannot be reused but itself becomes a waste. Polypropylene fiber mats and pellet beds are particularly appropriate, since they are resistant to most chemicals and are easily incinerated. Beds of polypropylene "sand" in the ten micron size range, for instance, are well suited for removal of heavy metal hydrated oxide slimes from hydrochloric acid recovered from the incineration of chlorocarbons.

Adsorption

One of the principle sources of sticky solids in recovered hydrochloric acid is traces of calcium and magnesium chloride which get into incinerator offgas and come over into the scrubbing system as slowly soluble sticky oxychloride. One of the ways to minimize such carryover is to use liquid/liquid adsorption to remove hazardous chlorocarbons from wastewater and eliminate the need to decontaminate the entire wastewater steam by incineration. That is particularly effective when carried out before discharge of the strong wastewater into primary treatment, since the hazardous contaminant is then concentrated in a small volume of easily incinerated fuel oil rather than in a larger amount of primary sludge which is considerably more difficult and expensive to incinerate.

The main design criterion for liquid/liquid adsorption is the partition coefficient, or relative solubility of the contaminant in the two phases. That is quite high for many organics between aqueous solutions and fuel oil, so a few mixer-settler stages can usually achieve essentially complete removal of the hazardous component. The combination of fuel oil adsorption and sweep floc precipitation as physicochemical waste minimization pretreatments can compete with activated carbon treatment for removal of some kinds of nonbiodegradable components. They have the advantage of requiring relatively small and economical additional equipment compared to expensive full stream packed bed granular carbon adsorbers.

Ion Exchange and Permeation

Two related technologies which fall somewhere between crystallization and adsorption are ion exchange and permeation. Ion exchangers are insoluble but porous materials which can selectively react reversibly with certain ions, such as heavy metals, thereby removing them from solution. Permeators are insoluble but porous materials which can selectively absorb water from solution, thereby leaving the ionic contaminants behind. In both cases the result is separation of a solution into two parts, one of which has most of the water and the other most of the salt.

The trick when dealing with materials in solution is to make sure that everything is dissolved. There is a tendency for colloidal slimes to be present which can accumulate at interfaces and slow down access to the interior of ordinary ion exchange materials which have a gel-type structure. That problem can be avoided to some extent by using macroporous resin beads, which are effectively agglomerates of very fine resin powder with internal crevices and pores. The surface/volume ratio is therefore much higher, and mass transfer rates less affected by slime.

Regardless of the physical geometry of the resin, the amount of material which can be captured is related to the residual concentration in solution. It follows that to capture most of a contaminant from solution, the concentration on the resin cannot be very high either. That leads to the concept that ion exchangers tend to operate in a semibatch mode. They start out with a low and uniform concentration of contaminant throughout the bed. As liquid moves through the bed, a concentration wave of captured contaminant moves through the bed much more slowly than the bulk liquid velocity. Beds are typically used two out of three in series in order to make sure that the capacity of the first bed is used up before the wave front breaks through the second bed. The third bed is then switched into the system backing up what was previously the backup bed (which is now the bed being bulk loaded), while the spent bed is taken offline for regeneration.

A typical example of operating in such a semibatch mode would be the polishing of a wastewater from a metal finishing operation which contains trace amounts of a valuable but hazardous metal such as silver. The metal is gradually accumulated on the ion exchanger, to the point where the ion exchange material can be incinerated to recover the metal in a usable form.

A somewhat different approach is to have the liquid to be treated flowing between nozzles in a column, and move the ion exchange material itself by stages from the liquid outlet (weakest solution) to the liquid inlet (strongest solution). This is particularly good when dealing with high concentrations of material which would require frequent regeneration.

Permeation represents another approach to that sort of problem. It is the application of the scientific principle of reverse osmosis. Osmosis of course is the diffusion of solvent (usually water) through a membrane from a weaker to a stronger solution. The concentration gradient is the driving force. Reverse osmosis causes solvent to move from a stronger to a weaker solution under the influence of some other driving force strong enough to overcome the concentration driving force. That would typically be either hydrostatic pressure or electrostatic field. There will obviously be a tradeoff between flux rate and selectivity, with membranes capable of generating purer solvent having lower capacity per unit area.

Reverse osmosis systems are perhaps best known for their capability of producing good quality drinking water from brackish or saline water sources. They are a cost-effective alternative to expensive distillation. They are especially effective in pretreatment of water to be deionized as feedwater for boilers or plating rinsewater, since by removing the bulk of soluble salts before ion exchange they minimize the amount of strong regenerant chemical solutions which must otherwise be treated for disposal.

Azeotropic Distillation

There are times when classical distillation is the appropriate technology. That is particularly true when it is only necessary to remove a relatively small amount of material, for instance water formed by the nitration of organic materials. Ordinarily it would be necessary to purge a large amount of mixed acid in order maintain its strength. It would typically be bucked up by stripping with hot dry combustion gases. A different approach would be to avoid the need to remove wet acid from the system at all, by stripping off water as fast as it forms with hot dry organic vapors. This azeotropic distillation is the equivalent of steam distillation, but in reverse. It is energy efficient since most organics have relatively low heat of vaporization compared to the energy losses in conventional acid strippers.

Waste Acid Incineration

Acid which has been contaminated with high boilers must be regenerated by incineration back to sulfur dioxide gas which can be used to make fresh acid to be recycled back into the process. Conventional spent acid regeneration plants require more heat input than is possible burning spent acid alone, therefore must produce more acid than they recycle. Finding a market for that acid these days may not be easy, since most customers are only interested in buying acid which you are willing to take back for regeneration or disposal after they are finished using it. We are presently involved with several patented developments which make it possible to minimize both the amount of new acid which must be disposed of from a spent plant and also the amount of purge acid required to flush out ash coming in with the feed.

The key to minimizing new acid is to reduce the influx of inerts into the system. That is accomplished in practice by using oxygen enriched combustion air, by controlling oxygen leaving the spent furnace to unusually low levels, and by taking advantage of all opportunities for heat recovery. Fast measurement and precise feedback control of oxygen is particularly critical, since spent acid sludge can vary from almost pure acid to almost pure organic in a matter of moments.

The key to minimizing purge acid required to flush out ash is to use a quenching scrubber designed to capture the flyash while passing the sulfuric acid mist coming from the spent furnace and its waste heat boiler. Conventional practice uses a spray tower cooler followed by condensing scrubbers. Ash getting through the spray tower contaminates the condensate and requires that it be purged. By using our patented and economical reverse jet scrubbers, we can catch the flyash before it gets into the condensers, and minimize the required amount of condensate purge.

Dry Scrubbing

Disposal of wastewater from any kind of gas scrubbing system is coming to be more and more of a problem. We have started moving in the direction of building incinerator offgas systems which are zero-discharge so far as liquids are concerned. We do that by using two different kinds of technology for capturing acid gases. Suspended particulate we catch separately using dry fabric filters or electrostatic precipitators. Where acid gas cleaning requirements are moderate, as in acid rain control, it is possible to use "dry scrubbing" for removal of up to 80% or so of sulfur dioxide. Where acid gas cleaning requirements are more stringent, it is necessary to use wet scrubbing, with recycle of scrubber effluent to a spray dryer taking advantage of waste heat from the incinerator.

The name "dry scrubbing" confuses many people, who expect scrubbing to involve mass transfer between a gas and a bulk liquid. Dry scrubbing is in fact not that different; the reactive liquid however is in the pores of a finely dispersed powder rather than being present in a bulk form. The technology goes back at least to World War I, where soda lime was developed as a dry scrubbing packed bed for use in gas masks. Soda lime is still a preferred material, although it is typically used these days as a dilute dispersion. Uniform dispersion and control of relative humidity are critical to the successful application of dry scrubbers.

Spray Drying

Uniform dispersion and control of relative humidity are also critical to successful operation of spray dryers, although for different reasons. The main design tasks are to accomplish complete drying in a vessel of reasonable size without getting sticky deposits on the walls. Once salts have been converted to a dry powder, there remains the problem of disposing of them. That would typically be to a landfill. When a significant fraction of the salts are water soluble, salt fixation with Portland cement may be required.

Sludge Incineration

Sludges containing substantial amounts of organics would typically be incinerated to get the volume down as small as possible. Sludge incineration is one of the areas where there is plenty of room for innovative technology. Multiple hearth furnaces and rotary kilns are the standard technologies. Some of the newer technologies involve fluidized bed systems. We have been successfully burning biosludge for years along with coal in stoker-fired boilers equipped with fabric filters. We are presently experimenting with burning pumpable biosludge in our patented cyclonic furnace: the goal is to come up with a retrofit burner for existing suspension-fired boilers which would be capable of burning biosludge along with conventional fuels.

The examples I have discussed today represent the creative innovations of many people over a period of years. We had our own exciting DuPont symposium on waste minimization last year. We have been looking forward to this meeting at Whippany in order to compare notes with the whole industry.

FIGURE ONE

TYPICAL POTENTIALLY HAZARDOUS LIQUID WASTES

* USED CRANKCASE OIL FROM MOTOR VEHICLES
* SPENT CUTTING OIL EMULSIONS FROM METAL MACHINING
* METAL-FINISHING WASTE (SPENT PICKLE, PLATING BATH, RINSEWATER)
* WASTEWATER FROM MANUFACTURE OF INORGANIC COMPOUNDS
* WASTEWATER FROM MANUFACTURE OF ORGANIC COMPOUNDS
* SPENT MIXED ACID FROM NITRATION OF ORGANIC COMPOUNDS
* SPENT SULFURIC ACID CATALYST FROM PETROLEUM PROCESSING
* HIGH BOILERS FROM PURIFICATION OF PETROCHEMICALS
* HIGH BOILERS FROM PURIFICATION OF CHLOROCARBONS

FIGURE TWO

PROCESS MODIFICATIONS TO MINIMIZE WASTEWATER EMISSIONS

DECONTAMINATION BY SEPARATION OF HAZARDOUS COMPONENTS FROM WATER:

* CRYSTALLIZATION
* FILTRATION
* ADSORPTION
* ION EXCHANGE
* PERMEATION

DECONTAMINATION BY SEPARATION OF WATER FROM HAZARDOUS COMPONENTS:

* AZEOTROPIC DISTILLATION
* WASTE ACID INCINERATION
* DRY SCRUBBING
* SPRAY DRYING
* SLUDGE INCINERATION

Waste Reduction at a Paint Plant
an OE Approach

Presented by
R. A. Mead
Coordinator, Environmental Affairs
E. I. Du Pont de Nemours and Company
Wilmington, Delaware

155.a

ERRATA SHEET

WASTE REDUCTION AT A PAINT PLANT
AN OE APPROACH

Presented by R. A. Mead, E. I. du Pont de Nemours & Company, Wilmington, DE, 19898 at NJDEP Hazardous Waste Reduction Audit Workshop, Birchwood Manor, Whippany, NJ, November 17, 1987.

Page 4, third line from bottom:

- cartridge size should be 250 micron (not 150).

Page 5, line 2:

- " eventually needed a 150 or even a 100 micron..."

Page 5, lines 3 & 4:

- "batch cards were changed to START with 150 or 100 microns on the product lines based on history cards."

Page 5, line 6:

- "....were used (all 150 or 100 m.)..."

Page 5, line 10:

- "....not taken increased yields."

WASTE REDUCTION AT A PAINT PLANT
AN OE APPROACH

Waste reduction or minimization is not a new objective. Reduction of cost by eliminating unwanted and unneeded waste is an economic goal long pursued by process engineers. We all know that less waste means higher yields, which in turn results in lower unit costs and ultimately more earnings for the innovative firm. In addition to the dollar value in increased yields, the foregone waste management costs for treatment and disposal compound the economic return of minimization efforts. Concurrently, we are all well aware that the 1984 RCRA Amendments made instituting a waste minimization program a regulatory requirement.

Thus, we can see that there are dual driving forces to encourage establishment of such programs in any operation that creates waste -- especially hazardous waste. The initiator of any one waste reduction program can come from one of three directions:

- Desire to increase yields to bolster profits
- Need to make less of a waste that is particularly difficult or expensive to dispose of
- Direct effort to reduce waste generation .

The result can be the same in terms of cost improvement and waste reduction regardless of the initial impetus. A waste minimization program can make use of efforts driven by any or all of the three motivators.

In plants where OE, or Organizational Effectiveness, is an active philosophy, participation is a key word. There is no better arena to employ OE techniques of involvement than in waste minimization! Waste is not generated by the plant manager! He may dictate or encourage such a program, but to increase the effectiveness of waste reduction, one **MUST INVOLVE** the workers who actually generate the waste. Of course, process engineers and line supervision -- especially first line -- must be on the team to provide technical expertise and action for implementation.

I would like to discuss an success story in one of our paint plants and give recognition to the site environmental coordinator, John Lang, as the spark that got this program underway. We had initiated some yield improvement programs through the technical organization prior to John's approach with some success. The best example was a division-wide implementation of product line "pigging". For those of you unfamiliar with this technique, it involves pushing a flexible plastic "pig" or bullet through pipe lines containing paint with nitrogen gas pressure. Paint normally left for the washing procedure is pushed out ahead of the pig and packaged -- resulting in a yield improvement **AND** a reduction in the amount of wash solvent required to clean the line. This program required installation of pig "launchers" and "catchers" and in some cases, larger lines from mixing tanks to filling equipment.

However, today I want to emphasize the approach John Lang used to involve many segments of the plant to find possible waste reduction opportunities and implement a path forward to capitalize on these opportunities. John, as the site environmental coordinator, was given the responsibility to initiate the formal RCRA waste minimization program. The initial questions were many:

- Who is going to do this work?
- What organization will be required?
- How to find the reduction opportunities?
- How to inventory waste generation points?
- How to implement?
- What will be management support? At what intensity?

Fortunately, the plant manager was squarely behind the program. John realized that to accomplish his goal, he needed a "broader brush" approach than he alone could conceptualize.

He carefully selected a Hazardous Waste Management Committee (HWMC) consisting of three operators from various site areas, one process engineer, one first-line supervisor, and, for direction, himself. As the program went along, the committee would tap whomever they needed for specific projects to join them temporarily. The purpose this group developed was to implement a waste minimization program through training and communication to the whole plant in a way that controlled waste generation and fostered minimization so that significant cost reductions would be attained.

The waste minimization program that was developed was very, very simple, as John put it. There were four basic concepts:

- Identify where all the site waste was generated. This involved tracking each waste stream back to its source and do some quantification.
- Identify **WHY** this waste was generated and under what instructions, Area Operating Procedure, or impetus was it first generated. Was it part of doing something that had "always been done" per past practices or was it something established for a compelling reason -- such as quality. Could it be

established as something really not part of doing business today -- and thus directly eliminated??

- Establish changes in processes and procedures to get the waste generation down. Be sure to watch for the interaction with your changes -- some might increase waste somewhere else OR create more reduction in a synergistic manner!

- Review any new process, new equipment project or operating changes **BEFORE** line organization approval to obtain the HWM Committee approval.

The HWM Committee met every week at the beginning. After several months they reduced their meetings to monthly and occasionally less frequently. There were instances where the operators involvement was so intense that they came to meetings on their own time because they were on shifts!

Emphasis was placed on a blend of the operators' experience and the process engineer's expertise and investigative skills. For instance, as they worked together to reduce waste and improve yields, the engineer naturally looked at the equipment and process with quality in mind. The operators looked more at procedures and Area Operating Procedures. But, by communicating and interacting, this blend focused on areas of opportunity. At the same time, because their mission was widely publicized, there was an influx of suggestions from other site personnel.

Their first task was to communicate to the entire site the importance of Waste Minimization and publicize the cost of HW disposal for the plant. Crew meetings were held everywhere in an effort to inform and raise awareness. Special meetings were held with the engineers to bring their awareness of their potential contribution in the area of process, procedure and equipment improvements. And after the program was underway, spot checks were made by the Committee to identify obvious wasteful operations.

Their second task was to create an accurate inventory of which wastes were generated by which operations. To get the needed handle on this, a site-wide waste container marking program was instituted by area. This was necessary because more than one area generated some waste of the same characterization. An example would be spent wash solvent.

After a careful and thorough listing of every waste generated at the plant, they were ready to start evaluating sources. One of the most obvious waste stream to focus on was the paint filter cartridges used on the filling floor. This plant produces automobile refinish lacquers and enamels, which require extremely good filtration to yield grit-free, high gloss products. Often the filtration step is the limiting factor in packaging rates because the filling machines can easily pump paint into cans faster than it can be pushed through the cartridges. Coincidently, a technical task force had been established to improve filtration quality -- called the "Grit Group"! Can you imagine the concern the HWMC had when appraised of this effort? Of course, to improve quality, this group would most likely make recommendations that would **INCREASE** filter usage in the name of QUALITY!!

Well, the benefits of communication and cooperation were demonstrated by the Grit Group and the HWM Committee working closely together. Grit was reduced and 50 percent fewer paint contaminated filters were generated! This was a resounding victory for both groups. Whoa, you say............how did they get to this result?

The first step of investigating the **WHY** questions was to look at past practices by the combined group. Let me give you some of the historical background so that you might appreciate the approach and technique the committee used.

- When a completed batch of paint was OK'd by the quality control lab, a filter setup was prepared by starting with a relatively porous cartridge (150 micron) because this would allow the fastest -- and most productive -- filling out of the batch.

- A gallon or so of paint was run through the filter and lines; a sample was taken and submitted to the lab for a grit and fineness check. The lab entered the filter rating and the check results on the test card under the paint formula in process.

- Should the fineness/filter check fail to produce the specified quality, a recommendation for a finer cartridge would be transmitted to the filling floor.

- This procedure would be repeated until the filtered paint was of the grit free quality needed for our customers. It was then filled our into the specified containers.

Some members of the committee felt that the "false starts" from trying coarser filters first might be counterproductive. A detailed review of the history cards in the quality control lab by the process engineer revealed a startling fact! A majority of the batches of the formulas with grit problems eventually needed a 250 micron filter to get the desired quality. Filter specifications on the batch cards were changed to **START** with 250 microns on those product lines. Results:

1. Quality was consistently higher for grit.
2. Eventually 50 % fewer cartridges were used (all 250 m.) which translated into 50 % less volume in this waste stream.
3. Cost savings for the filters not used and the extra samples not taken increasing yields.
4. Corollary waste reduction: lab waste stream down as fewer samples were submitted.
5. Corollary cost savings: less lab time spent per batch and less setup time by the filling line crew. Time lost in flow through the finer filters was more than made up for by less changing time!

This may not seem like much per batch, but the leverage was felt day in and day out over many batches. The second most significant achievement was the waste reduction. The most important was the proof that, after identification of the waste source needing scrutiny, a thorough questioning of **WHY** resulted in very positive waste reductions. The HWM Committee's process was working!!

Successes were publicized widely around the plant. Suggestions starting rolling in from all quarters!! Engineers were carefully screening present processes and scrutinizing future projects.

The next major waste stream to receive focus was the largest one of all: **spent wash solvent**. Quality efforts over the years had always stressed cleanliness between batches. The traditional approach was to use more solvent to "ensure" cleanliness. After all, wasn't the solvent recycled by distillation for reuse as wash solvent! Tank washing -- including the lines to and the filling machines -- was creating nearly 90 % of the hazardous waste. Another truism was established: go after some of the big streams where a one percent reduction is significant in pounds.

A thorough study of the operation of the "Rotojets" that had been permanently installed in every tank was undertaken. The habits of operators doing the cleaning between batches were carefully analyzed. The results again were somewhat astounding: there was no specific time to run the jets -- solvent valves were just opened and away they went until the operator finished whatever task he was working on in the meantime. They always gave the tanks a "good" cleaning -- but at what cost in quantity of wash solvent used. Of course the assumption that it was recycled for use again was also a false comfort, since the best yields ever attained on the plant thin-film evaporator were never 100 %.

How did they get at this unrestrained practice? The HWM Committee recommended a timer and solenoid valve be installed on each "Rotojet" solvent feed line. The timers could be set for 5 minutes or 2 minutes. The AOP was rewritten to specify a 5 minute wash to start followed by inspection and then subsequent 2 minutes washes and inspections until the desired degree of cleanliness was attained. Note that if an operator was tied up with other tasks, no large excesses of solvent would be sprayed in the tank. With extensive, uncontrolled sprayings no longer the norm, some standards for determining when the tanks were clean needed to be put in the AOP on cleaning. Concurrent with mixing tank cleaning, the lines, hoppers, filter casings, vibrating screens, and filling machines were washed in series with the same solvent fed by gravity. The committee developed a basic premise -- hardly revolutionary -- that if the wash solvent started to come out clean from the filling equipment after some number of timed jet spray cycles upstairs, then the tank must be clean. But how do you communicate the cleanliness check without running up and down stairs or running too many cycles. Easy! Have the operator upstairs check with the filling floor operator -- by hand-held radios. Of course, as you might imagine, a whole new era of communication developed quickly between the floors and productivity flourished (using waste minimization justified radios!).

With the total volume of wash solvent reduced -- I can't give you a percentage yet as this system is still being fine tuned -- the HWM Committee turned to look at the solvent recovery process. The still bottoms from wash solvent recovery remained the main waste stream of the plant. Using the thin-film evaporator with high pressure steam and vacuum, the still bottoms had traditionally been concentrated to 70 % and solidified upon cooling. At this recovery percentage, the engineers were sure they were creating the minimum amount of still bottoms.These "blobs" of resin, pigment, and some high boiling solvents, plasticizers, etc. were packaged in lined cardboard drums and incinerated in rotary kilns at RCRA facilities.

A look at alternatives and process balancing at the solvent recovery operation by the Committee with some extra engineering help revealed an interesting option. The optimum solids level was established at 30-40 % so as to keep the still bottoms pumpable. The outlet selected now was a fuels program for cement kilns. Ah, you say, "That increased the waste generated and reduced the amount of recycled wash solvent." Not all bad though. When the higher boiling solvents were left in the still bottoms, the resultant recycled wash was much more effective in cleaning the tanks, lines, and filling machines. This is due to the higher solvency of the "active" solvents -- such as the ketones and esters -- and a higher percentage of toluene and xylene in the wash. This effect, of course, will vary with the paint/lacquer formulations you might be manufacturing. Guess what synergistic effect this change in wash solvent composition had? Fewer number of "Rotojet" cycles were needed with the better solvency wash! A further waste reduction! A collorary benefit was substantially lower disposal costs -- even for a somewhat larger volume of still bottoms -- due to the fuels program costs being so much lower than rotary kiln incineration. Remember, the second part of the RCRA waste minimization requirements is to select the treatment/disposal method that reduces the toxic impact on human health and the environment. The still bottoms are exposed to higher temperatures and usually longer dwell times in most cement kilns than is required in RCRA incinerators and the inorganic pigments are captured with the cement product -- the ultimate encapsulation.

There are two other waste streams that have been successfully reduced by the Committee efforts. Pigments have been traditionally package in fifty pound paper bags. Lead chromate bags have been a waste problem with potential EP Toxicity and risk of unacceptable health exposures to handlers. Traditionally, exhaust systems have been designed to remove the dusts involved from the operators work area. The dust collectors on these systems yield a hazardous waste when they are emptied if you consume enough lead chromate (and other chromates). By switching to bulk titanium dioxide and returnable, reusable air pallet bags, the plant was able to halve their pigment dust and lead chromate bag waste streams.

The last investigative approach from the plant that I will mention is to look at similar or identical operations and ensure they are all running the same -- for instance, are the three parallel and identical pint/quart filling lines producing about the same amount of waste? Are all three operators following the AOP's that yield the least amount of waste? Of course, such an evaluation must consider other operating parameters such as quality and productivity when making judgements.

Some of the ideas for waste reduction come from outside the plant but need plant people to participate in divisional or departmental projects to reduce waste. Another waste stream that was identified as significant to the entire department was the discontinued finished product stock. This was mostly in the control of marketing, but site stock control personnel joined with stock analysts at department level to attack this problem. The result is a new "leveling" computer program to start up in early 1988 which will search for stockkeeping units at 2 plants and 27 warehouses for transfer before asking for another batch to be made as the product movement slows or it approaches time of obsolescence. Transportation costs for shuffling finished product are becoming insignificant when compared to Hazardous Waste disposal costs. Reworking of obsolete products into newer ones is also being actively pursued by an inter-plant team.

In summary, the approach of the Moberly, MO plant designed by John Lang, was to assemble a team with a wide variety of skills and experiences to foster as wide an involvement of site personnel as possible in the waste reduction effort. This Hazardous Waste **MANAGEMENT** Committee has been very effective in motivating the entire plant. Waste disposal costs were widely publicized, as were successful waste reduction efforts. Using OE frameworks, they established a communication and training program to foster participation site wide. Their program was simple:

- Identify all waste streams
- Identify **WHY** this waste is generated
- Identify and implement process, equipment and procedural changes to reduce the waste
- Review all on-going changes in the plant to discover ways to reduce waste or to prevent adoption of changes that would increase waste generation

This OE approach did get the involvement and participation it was designed to obtain.

R. A. Mead
E. I. du Pont de Nemours and Company
Wilmington, DE 19898
October 8, 1987

Waste Reduction in the Paint Application Industry

Presented by
Herbert S. Skovronek, Ph.D.
Environmental Services
Morris Plains, New Jersey

PAINT APPLICATION: WASTE MANAGEMENT

by
Herbert S. Skovronek
ENVIRONMENTAL SERVICES

In 1986, 967 million gallons of paints and coatings were shipped by the US coatings industry according to Chemical & Engineering News. If we conservatively say that these coatings contain approximately 50% solvents and other volatile materials, and if we recognize that the application and curing of these coatings occurs with the loss of all of those solvents by evaporation, we have put almost 0.5 billion gallons, or 500 million gallons, or 4 BILLION pounds of solvents into the air. Certainly, some of today's coatings contain much more than 50% solids and some of the solvents are non-hazardous while an increasing portion contain water. And, it is certainly true that some portion of the hazardous solvents are trapped, collected, or treated in some way, nevertheless, the conclusion remains quite clear that the use of coatings currently puts a great deal of undesirable pollutants into the atmosphere. The scenario with other components may, on a global basis, be less overwhelming since the non-volatile components tend to remain on the substrate to which they are applied, but still can reach high levels. For example, while only 10% of the solids may be lost as overspray or other production losses, and 90% of those solids may be trapped in some fashion, this still suggests that 40 million pounds of paint solids are lost directly. In addition, many of the coated substrates ultimately are disposed of, leading, potentially to downstream pollution, either through corrosion/erosion or as incinerator ash or landfill runoff.

But, perhaps it is best to first look at the sources and the means of controlling many of the losses at these sources -- at least for those that are controllable. I will try to devote this presentation to the opportunities that exist in the application sector for controlling and minimizing waste generation and discharge.

The idea of waste minimization appears to be relatively new. However, I find this somewhat surprising since it always seemed to be good engineering practice to look at all aspects of a problem and all means of preventing ultimate environmental insult. This means examining the total scenario and considering all methods of minimizing waste. For example, while my colleague may not appreciate it, one alternative that must be considered is: "why paint?" Bear in mind that you, the fabricator, may not want to be a painter.

In any review or audit of a waste generation/control problem, there are several questions or basic groundrules that need to be examined. These include:

a. Know what you've got
b. Know where it's going
c. Know if where it's going is socially acceptable
d. Look at the costs (all!) for the current practice

e. Don't just look at the waste, but look at the whole operation/process/sequence.

To try to generalize, we might have the following scenario:

> I sell widgets that need to be protected from certain exposure. That might be refrigerators, bridges, home siding, automobiles or safety lines down a highway.
>
> Traditionally, I have used paint, in its most generic form, to do these jobs. To do this I have purchased a product to certain specifications, made color adjustments and dilutions with solvents, and applied the modified product to my substrate by brush, dipping, spraying, or some modification of these techniques and "curing" the product coating by heat, time, or some other technique. Before I applied the coating I may also have prepared my substrate by sanding, degreasing, etching or priming. As part of my quality control, I invariably have had some losses due to unacceptable quality, substrates that either had to be discarded or reprocessed by touchup or stripping and recoating.

What are my wastes along the way? Depending on my operation, they might include dusts and solvents from preparation, excess or off-specification coating materials and container "stickage", equipment cleanup wastes, drippage or overspray, solvent emissions during drying and curing and paint stripper wastes or decomposed or dissolved coating materials from reprocessing. In addition, there probably also are secondary wastes from maintenance opeations and from ongoing environmental efforts (e.g., loaded filters). In most operations, the two largest wastestreams would be paint-contaminated thinner (equipment cleaning) and solvents lost during application. Clearly, then, these are the primary targets, although other "opportunities" should not be ignored.

In trying to get control of the overall or total process, it is necessary to examine -- in detail -- all aspects and all steps in the operation. In many cases, such an analysis will uncover inefficiencies that have crept into the operation in spite of management's best intentions. These are most easily corrected and can have a major impact on material use (and cost) and, ultimately, on waste generated. Some examples along this line might include:

- gradually increasing the volume of coating product purchased to be sure that there is enough for the job;
- decreased filter efficiency as filter life is extended because of the cost or the inconvenience of replacement;
- increased application rates to assure coverage; and
- poor housekeeping and equipment maintenance.

Even before correcting such problems, we need to go back and ask ourselves some basic questions. For example:

Is a coating needed?

> Can another coating/protection system be used? In many architectural areas, protective synthetic coatings (paint) have been replaced by what I call "pre-rusting". What about good old galvanizing?
>
> Can the part be made from a different material? Plastic may be "better" and may even allow incorporation of color. Maybe the stainless steel or fibreglass car body isn't that bad an idea when you look at all the costs involved in painting a car. (Of course, alternate materials of fabrication may present their own environmental problems.)

But, let's assume that we conclude that a paint coating on an existing substrate is necessary. What economies can be achieved by limiting the options I offer my customers (do I really need fire engines in red, orange and yellow?) Limiting my colors (or other properties) reduces my inventory (and eventual coating wastes), reduces my cleanup frequency, my cleanup wastes, my lost production time, and simplifies my scheduling woes. If I look at all costs, perhaps I'm better off offering only the highest of my quality options, even if the preliminary cost seems to be higher until I consider all the factors and MARKET the high quality. Finally, if I must offer or have available a range of colors or properties, am I better off buying paints to those specifications or should I develop my own color matching capability that allows me to reduce waste (wrong colors, excess supply, etc.). Does ready availability of colors improve my ability to schedule my operations and thus, again, reduce my cleanup problems?

Often, offering a wide range of services or products complicates my business more than it's really worth. Careful, hard business analysis may show that becoming a specialist in one phase of the business may allow me to do a better job in that area while minimizing my peripheral problems such as inventory and waste management. If I must service my customers with variety, perhaps I can make an arrangement with a (friendly) competitor so that I do all the red work and he does all the green work?

Perhaps the next question to consider is what sort of application do I need to use: dip, spray, or brush, each with its own sub-options? Realistically, most commercial application today probably is either by dip coating or by spray application. Both offer environmental opportunities and present environmental problems that need to be considered as part of the operational and cost analysis. While this question may have been answered when you opened your door for business several years ago, has your business -- or your problems -- changed enough since then that a reevaluation is warranted -- even if it means a major capital expenditure in the near future. Certainly energy, environmental and employee health questions have changed over the past several years.

Let's look more closely at spray painting as an example of how decisions may need to be made. A similar scenario can be developed for dip coating or others. We'll assume that decisions have already been made that (a) the substrate is unalterable; (b) a coating is needed; and (c) spray application is the most efficient means of achieving the needed coverage.

We've recognized that some form of spray booth is going to be needed to contain the overspray and fumes, provide an OSHA-complying workplace -- and keep out quality-damaging dust from other operations. Today, energy considerations also need to be a major factor in how you schedule your use of that booth and, perhaps in the products you select as your basic coating system. Unfortunately, energy cost has become a very volatile and uncertain question, depending on the mid-east status at the moment. And, since most coatings are derived from petroleum products and use energy for curing, petroleum cost impacts in at least two ways. Employee health considerations are becoming another major issue, again mandating an efficient, pollutant free work environment achievable by increased ventilation -- or a change in products used. But, while OSHA says get it out of the shop, EPA says don't put it into the outside environment.

Such factors are forcing manufacturers (fabricators/finishers) to look at new options in coating systems (in the broadest definition of "system"). Today, alternate systems range from waterborne coatings to high solids coatings and powder coatings. These newer systems tend to minimize or eliminate the environmental, health and fire problems related to solvent emissions and may also have other advantages such as the ability to recover and recycle overspray (powder coatings). However, these benefits do come at various costs; products may be slower or require more energy to cure, more sophisticated air handling systems may be needed to assure dust free atmospheres, totally new equipment may be needed (powder coating) and new hazards such as dust explosions need to be addressed. For example, and in spite of the foregoing comments, one firm, Bergstrom Manufacturing, reduced labor and material cost by going to a poweder coating system. Energy requirements for exhaust air was also reduced by 90% and that required for curing was reduced by 50%. Another, Steelcase, reported a 40% reduction in VOC emissions by going to a hi-solids coating and Stanley Works experienced an 87% drop in emissions by changes including a shift to a dip coating with a water based coating for shelf brackets.

With new coating systems also have come new curing techniques that offer benefits and problems that need to be considered. Radiation curing with ultraviolet light or electron beams is an exciting new opportunity to reduce energy requirements and volatile organic emissions, but, at present, such systems may require redesign of substrates since they only work on thin coatings and for "line of sight" coating. The latter technique also requires an inert atmosphere to prevent "poisoning" of the curing mechanism by oxygen.

But, let's go back to the conventional spray coating systems that most firms are still using. What are its problems and what can be done within the system to minimize these problems or their effects? Whether it's an auto body shop or a fabricator painting medicine cabinets, the problems tend to be similar: Volatile organic solvents lost during application and curing and paint solids lost as overspray during application. If we look at a typical small but up-to-date body shop we probably are applying less than 2 gallons of paint coating materials per day. These materials are diluted for application with approximately an equal volume of thinner, i.e., another 2 gallons. The shop has a spray booth, probably installed within the last few years to meet employee health, product quality and fire regulations -- at a cost of between $20000 and $50000! When one sits down to develop the air permit for the stack from such a facility, one finds:

Material use: 2 gallons paint at 50% solids/50% VOCs or, at 8 lb/gal, approximately 8 lbs solids and 8 lbs thinner.

2 gallons of thinner at 100% VOCs or, at 8 lb/gal, approximately 16 lbs of thinner.

Overspray estimated at 10%

Booth filter capture 90% of overspray solids

Emissions: Solids: 8 lbs x 10% overspray x 10% loss = 0.08 lb/day.
VOCs: 8 lb(paint) + 16 lb(thinner) x 100% loss = 24 lb/day.

While these numbers are very approximate, they probably are "fair"; overspray may be greater than 10% but filter capture should be better than 90%. (An article describing an alternate technique for pressure spraying suggests that conventional high pressure (60-90 psi) guns produce as much as 60-65% overspray (WASTE!) while newer, low pressure guns (1-3 psi) can reduce overspray to less than 20%.) At this time I know of no practical control system for the VOCs from a small facility's spray booth. One could say that 24 lbs of VOC are "de minimus"... at least until we realize that there are about 2000 such shops in New Jersey, with a high concentration in the very urban areas that are of most concern for their VOC emissions. In addition, bear in mind that this is a 10 billion dollar business (collision and repair) that used 66 million gallons of paint in 1986!

What can such a shop do? The paint manufacturers, while seeing the need for improved VOC control coming, are the first to admit that alternate, less polluting systems such as waterbased coating systems for refinishing are several years away - at least - even though they are now finding use in manufacturing plants. There are condensation, carbon adsorption, and incineration systems available for the large user, but these systems are not practical nor cost-effective for small facilities at capital costs of $50000 and up. There is limited availability of carbon filters for such systems, but little evidence that they can do more than cosmetic cleanup of VOCs from such installations (collecting 24 lbs of VOC/day may require about 125 lbs of carbon. Even if such filters were incorporated, their subsequent disposal becomes still another problem, unless a regeneration subsystem is also developed.

In other areas in such shops considerable headway has been made in reducing "fugitive" emissions. For example, spray equipment cleanup systems such as those marketed by Safety-Kleen reduce the amount of solvent used, contain all solvent and incorporate arrangements for pickup and off-site reclamation of the solvent.

In general, the size of such operations -- and the lack of technical expertise being applied to these problems -- precludes on-site recycle of the solvents. In the near future, hardware and other technical improvements may have to take a backseat to more mundane changes such as training employees to make less paint, waste less paint, and, generally speaking, avoid the unnecessary loss of solvent vapors.

As we move to larger operations where paint use is a full scale daily operation, we begin to see interesting options to minimize waste generation and loss. Smaller and smaller stills are becoming available that allow recovery of spent solvents from waste paint, equipment cleanup, etc. Naturally, the more a shop sticks to one brand and one product line, the more likely they are going to be able to reuse that recovered solvent. However, even still-recoverable paint wastes will continue to have limited value at the low production end. Reclaimed solvents can be used for equipment cleanup and some product dilution. Only in the largest installations is it likely that the capability will exist to use (and destroy) the solvents as a fuel supplement.

It has also been suggested that the partially evaporated sludge from such stills may be incorporated into an "undercoating" material to be applied to the refinished vehicle, thus avoiding its ultimate destination as hazardous waste. The solvents remaining in the "undercoat" are then lost as that product dries, but replaces other, virgin solvents that would have been evolved. Unfortunately, the current regulatory protocols, by which waste solvent going to on-site reclamation must be "counted" in a facility's waste volume, inhibits marginal shops from embarking on this investment. Once recordkeeping, manifesting, and pickup by a licensed hauler become necessary (100 kg), the added volume of recovered solvent becomes less of a detriment and less of a motivation for recovery. In fact, by reducing the volume, the site becomes a less attractive pickup and finding a reputable firm that will make the stop every 90 days becomes a serious hurdle. I should note one interesting approach that has been taken. One industry group has cooperatively purchased a small still. While use by any one member would not have been cost-effective, the part-time use by several shops may make solvent recovery more attractive for all participants. However, where this would fit in DEP's view, as a portable TDS facility requiring permitting or as an on-site recovery system (as it will be in each shop when used) is an interesting question. Clearly, if DEP takes the first view, it would seriously hamper the success of this effort.

Continuing with the larger facilities such as fabricated metal manufacturers, we begin to have other options. Both carbon adsorption and refrigeration/condensation systems are available for recovery of solvent vapors, but only for such larger systems. Fabricators include firms such as American Environmental International, Inc., who market a chiller or condensation system for recovery of printing solvents. Cost seems to start at about $50,000, which again reflects the unattainability of such systems for small shops where the spray booth itself may have cost, as noted earlier, $20-50,000, and where space is at a premium. Depending on the variability of the coating systems used during a production campaign, the recovered solvent may be reused in the process or may be useful as an fuel supplement to the curing ovens. Again, only larger facilities using oil or gas fired curing ovens would be able to take advantage of such supplementation. Carbon adsorption systems -- with on-site regeneration and solvent recovery -- probably start at about $100,000 and require a source of steam for regeneration. Incinerative and catalytic destruction systems are also available but they offer little in benefits besides the destruction of the wastes.

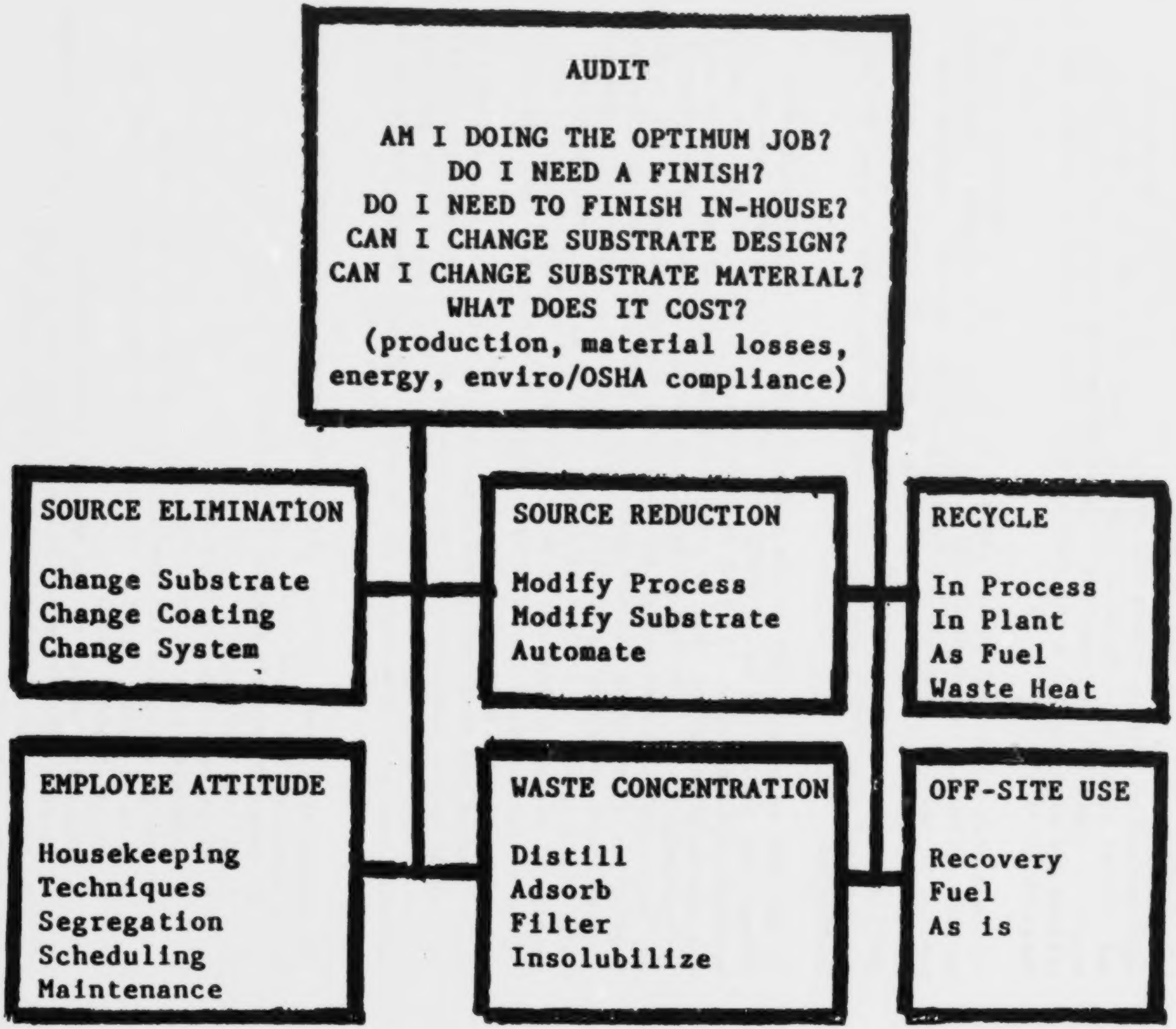
At least when waste destruction appears to be the most attractive, still another option is to reexamine the total system. For example, while coil coating of steel or aluminum has lost significant markets, new ones are being developed including the precoating of metal for subsequent fabrication into furniture, siding, etc. This offers the distinct advantage of eliminating all wastes related to the painting step for the fabricator.

In the area of waste paint solids minimization (recovery, reclamation, reuse), the technology is, frankly, not very sophisticated. From an economic point of view, it is in the applicator's best interest to control his substrate design as much as possible to minimize dragout or the need to overspray to get coverage of difficult areas. Electrostatic spraying may be a significant advantage in minimizing the amount needed for uniform coating while producing minimum overspray. With the exception of powder coating, once overspray is generated it is unlikely that it will have any value and disposal of sludges or loaded filters may be a real problem because of the metal content of such materials. In fact, disposal cost may be a driving force toward other changes in the system that can reduce the volume of such material.
While vendors may be pursuing modifications in both materials and systems that would enable fabricators (i.e., applicators) to recover paint solids and solvents, their emphasis is, naturally, on the larger, more lucrative markets where such investments can be made. In most cases, the technology has not yet filtered down to the smaller operations.

In summary then, what are some things that every fabricator/applicator can do to minimize his waste load.

- Consider whether coating is needed
- Minimize inventory
- Minimize changes in products, colors, etc.
- Schedule for minimum washup requirements
- Design substrate and handling system to minimize overuse
- Look at total cost for coating operation, including energy and waste disposal costs
- Segregate wastes to the maximum extent possible
- Install OSHA/EPA vapor collection systems with an eye to recovery
- Increase cooperation with competitors, customers
- Specialize
- Lobby for changes in regulations that stimulate reuse and reclamation/recycle, whether on-site or off-site

Herbert S. Skovronek
ENVIRONMENTAL SERVICES
88 Moraine Road
Morris Plains, NJ 07950


AUDIT
AM I DOING THE OPTIMUM JOB?
DO I NEED A FINISH?
DO I NEED TO FINISH IN-HOUSE?
CAN I CHANGE SUBSTRATE DESIGN?
CAN I CHANGE SUBSTRATE MATERIAL?
WHAT DOES IT COST?
(production, material losses, energy, enviro/OSHA compliance)
SOURCE ELIMINATION
Change Substrate
Change Coating
Change System
SOURCE REDUCTION
Modify Process
Modify Substrate
Automate
RECYCLE
In Process
In Plant
As Fuel
Waste Heat
EMPLOYEE ATTITUDE
Housekeeping
Techniques
Segregation
Scheduling
Maintenance
WASTE CONCENTRATION
Distill
Adsorb
Filter
Insolubilize
OFF-SITE USE
Recovery
Fuel
As is

AUTO REFINISH SPRAYBOOTH -- PERMIT DEVELOPMENT

MATERIAL USE: 2 gallons paint at 50% solids/50% VOCs or, at 8 lb/gal, approximately 8 lbs solids and 8 lbs thinner.

2 gallons of thinner at 100% VOCs or, at 8 lb/gal, approximately 16 lbs of thinner.

Overspray estimated at 10%

Booth filter capture 90% of overspray solids

EMISSIONS: Solids: 8 lbs x 10% overspray x 10% loss = 0.08 lb/day.

VOCs: 8 lb(paint) + 16 lb(thinner) x 100% loss = 24 lb/day.

BUT:
2000 SHOPS IN NEW JERSEY
66 MILLION GAL PAINT USED IN 1986
$10 BILLION SALES (COLLISION/REFINISH) IN 1986

The R&D Sector: Optimizing Waste Minimization Practices

Presented by
Elizabeth A. Holland
Senior Research Chemist
Safety Assurance Section
Lever Research, Inc.
Edgewater, New Jersey

THE R&D SECTOR: OPTIMIZING WASTE MINIMIZATION PRACTICES

Waste minimization in the research and development sector must be implemented in accordance with the premise upon which R&D is built; innovation and creativity. In a manufacturing situation, processes may be streamlined which maximize waste reduction. R&D however, may only optimize, or make the most effective use of waste minimization through creative implementation of a unique and facility-specific program. A variety of practices and procedures currently used in the R&D industry shall be reviewed for practical application purposes.

Following inception of the 1984 HSWA waste minimization requirements, the research and development sector recognized its unique inability to achieve measurably reduced levels of hazardous waste annually, as the practicable minimization of waste runs contrary to this sector's underlying principles and operating characteristics.

Whereas in a manufacturing situation, processes may be altered, streamlined, substituted, or decreased to maximize waste minimization, R&D may only optimize (on a case by case basis), waste minimization techniques currently available. Multivariate inputs do not allow for reduction design application nor do most recognized test methods utilize or specify reagents on the basis of their hazard potential.

It is believed that although some of the manufacturing sector's existing processes and technologies may be adapted for incorporation into laboratory and pilot plant areas, the most effective means currently available by which a minimization plan may be adopted is through creative implementation of a program which is tailored to meet the needs of the facility and qualitatively demonstrate waste minimization.

Lever Research, located in Edgewater, New Jersey has based its program upon the premise of R&D: Innovation and creativity. By finding new ways to optimize its hazardous waste reduction, the company increased employee involvement and awareness, gained acceptance of the program internally, and received positive feedback from State authorities.

Some of the methods Lever utilizes to minimize and reduce hazardous waste are facility-specific. However, it is believed the balance of these techniques may be incorporated into other R&D systems with no or minor revisions.

Like many other research institutions which do not qualify as small quantity generators, Lever Research maintains an hazardous waste storage facility. This facility must meet full RCRA compliance requirements because of the following conditions: Types and quantities of wastes generated; longer accumulation times required; unique characteristics of the waste streams; ongoing selection of disposal options in accordance with "best management practices", and; greater than 90 day time requirements for waste evaluation and processing.

Until now, no treatment activities have been performed at our site other than elementary neutralization and incorporation of "totally enclosed treatment facilities", as Lever's RCRA permit allows for storage activities only. However, following New Jersey's recent approval of "accumulated-waste treatment" without a permit (reference: The New Jersey Hazardous Waste Quarterly, Vol. 1, No. 2, 1987), the company intends to take full advantage of this option and incorporate this treatment exemption in order to reduce the volume and/or toxicity of hazardous waste destined for manifested disposal. The effect of this interpretation is expected to substantially contribute to waste minimization for generating processes which cannot be reduced by other "before generation" means.

Other than this new method of in-house waste reduction, Lever has deemed it appropriate to rely on support activities versus process control.

Lever's waste minimization program was strategically developed for incorporation with minor revisions into the company's existing RCRA program. It was initially determined, inception and acceptance of minimization practices would be implemented more rapidly and effectively if existing waste management guidelines were followed.

In developing the program, six key areas were defined as essential elements needed to create a viable, systematic process of rules. These areas are defined as follows:

-Corporate Commitment
-Institution of Site Procedures
-Incorporation of Communication Channels
-Education and Training
-Support Activities
-Feedback

In order to assess the program's value, each of these issues shall be addressed individually. Please note, as effectiveness is achievable only through the simultaneous enforcement of each variable, their interdependance will be referred to as well.

Corporate commitment. In order to gain commitment, the introduction of any new program must be evaluated for compatibility with the corporate mission. Lever developed its waste minimization program to meet the company's R&D philosophy of Innovation With Integrity. Although this statement refers to all areas of regulated compliance, the hazardous waste minimization concept encompasses all implications of this succinct phrase.

All companies must provide a written statement certifying the program's existence in accordance with State and Federal law. The existence of such a document though, does not necessarily preclude effective application and enforcement of program provisions. Therefore, an additional commitment to the development of a flexible program must be obtained from upper management in order to provide impetus and authority for implementation.

The effective approach which Lever used, is that of gaining acceptance through perceived value. By speaking in terms of real dollars, program implementation may be viewed as a viable opportunity to potentially reduce disposal costs, liability, and hazardous waste generated.

Institution of site procedures. In accordance with Lever's current waste identification program and procedural channels of hazardous waste handling responsibility, waste minimization practices were implemented through the currently existing system. A minor revision, consisting of the increase in involvement of the Shipping/Receiving and Purchasing departments in the procedural process was made, as these channels are utilized to provide measurable recordkeeping data.

Prior written notice of hazardous waste generation is received through the mandatory use of waste identification forms. The individuals primarily involved in the program's procedural signatory approvals are designated as those authorized and responsible for handling hazardous wastes generated by a particular source.

Primarily, the existing chain of command was followed in establishing procedural recognition of types and quantities of wastes to be disposed of.

Incorporation of communication channels. This is considered to be a key element in maintaining an effective waste minimization/reduction program as these channels provide feedback mechanisms for all on-site hazardous waste generators. In order to obtain maximum value from all site inputs, Lever has adopted a proactive communication strategy. It is based on an interactive relay of ideas which crosses and typically runs contrary to the procedural channels previously discussed, and encourages face-to-face communication. As each individual is his or her own generator, these individuals are most capable of providing new waste minimization and reduction techniques as they apply to specific activities.

Education and training. The training forum for Lever's waste minimization plan has become the annual RCRA training update meeting. Intermittent updates are further related through memos of proposed activities and ongoing discussions with hazardous waste coordinators and hazardous waste management team members.

The hazardous waste coordinator is an individual appointed in each department. Following participation in the training program and passage of the review exam, he or she becomes directly responsible for implementation of generator level RCRA activities and concurrently provides educational know-how for the generators within their department. The hazardous waste coordinator follows a written job description which provides guidance during hazardous waste handling activities, and; holds at least a bachelor's degree in one of the sciences (or equivalent experience). The coordinators' activities and training are included as part of their permanent record and related successes of waste minimization and reduction activities are identified for performance evaluation purposes.

As formally educated professionals, the employees lend a unique degree of expertise to the RCRA program, and also provide first-hand knowledge of departmental activities for identifying waste minimization opportunities.

Support activities. The actual minimization and reduction techniques employed at the Lever facility are numerous and varied. Although some of the activities are utilized for purposes of gaining corporate and employee commitment, i.e. returning materials to suppliers, most of these measures contribute in part to demonstrate an overall decrease with no single practice consistently contributing substantially more than another. The listed activities as they apply to either Research or Development and their subsequent application throughout the generation process, have been attached for reference.

Although the list of activities appears extensive, each practice is evaluated by the individuals performing the waste reduction activities on the basis of feasible introduction. As expressed earlier, research and development must adopt a facility-specific program and additionally, extend it in application to the level of individual generators.

Feedback. The last element to be outlined is also the most important in ensuring program effectiveness. Feedback concerning the existing program's viability is first and foremost obtained through application of minimization measurements as reported in the Facility and Generator Annual Reports.

Lever, as all other research and development institutions, could not calculate its waste minimization effectiveness on the basis of State established measurements. Therefore, the company chose as its baseline figure, budgetary expenditures less capital expenditures. As project priorities and resultant activities (i.e. waste generation) vary, time and salary allotment to specific SIC-coded activities is deemed to be a measurable baseline. Although it is not a true indicator, further clarification is given in the reports to explain any discrepancy between the calculated figures and efforts applied.

Additionally, an in-house evaluation program has been established through the effective use of communication channels in order to provide an ongoing indicator of waste minimization successes and failures.

In conclusion, six basic elements have been defined as essential in the development of a workable, measurable and enforceable waste minimization program. Although there are currently no quantitative measures by which to gauge compliance, Lever believes it is the qualitatively measured "good faith effort" employed which shall determine whether or not the company has fulfilled regulatory requirements. Furthermore, these practices will assure recognition of the unique conditions under which the R&D sector generates hazardous waste and more importantly, aid in the development of realistic hazardous waste minimization and reduction requirements in the future.

ATTACHMENT

IN THE LABORATORY

Before Generation	During Generation	Following Generation
-Evaluate -Search for alternatives -Return to suppliers -Proper labeling -Safe handling -Education -Collective use	-Separate hazardous from nonhazardous -Dewater/Avoidance of dilution -Compatibility monitoring	-Recycle -Reclaim -Resell -Condense -Manifested disposal using "best management practices"

IN THE PILOT PLANT

Before Generation	During Generation	Following Generation
-Evaluate by-products/end-products -Search for alternatives -Return to suppliers -Safe handling -Enforce OSHA HCS -Computerized inventories -Incorporate totally enclosed treatment facility -Substantiation of process prior to testing	-Combine activities -Separate hazardous from nonhazardous -Reduction of batch size	-Container reuse -Rework formulations -Resell -Manifested disposal using "best management practices"

Waste Reduction in the R&D Industry

Presented by
Steven C. Rice, P.E.
Corporate Ecology
BASF Corporation
Cherry Hill, New Jersey

1) Diversity: Each lab or pilot unit area is always working on a wide range of investigations in diverse interest areas. Approaches suitable in one area with one set of constraints may be quite unsuitable for another area.

2) Variability: The nature of research work requires that different techniques and different activities be attempted, very unlike operating plants. A problem once resolved for one unit may no longer be resolved a few days or weeks later since the work, the kinds of materials or their amounts may have changed. New circumstances are constantly being presented as new work is being initiated.

3) Originality: One of the many purposes of R&D is to do new work, often in new areas, such that one can rarely go to published literature to find out how someone else resolved a particular environmental issue. Also, the project's environmental impact and waste generation characteristics may not always be clear at the beginning of the effort.

Therefore, waste reduction for research and development activity is much more than a "one shot deal" to implement. It becomes more of an effort to create a mental attitude within each research scientist or engineer to think of waste reduction continually in all phases of his or her work.

Waste Reduction Opportunities And Experiences

Waste reduction opportunities and experiences in the R&D industry are as varied as the nature of the work. There are several approaches that can be taken, the advantages and success of which will depend on the specific situations at the specific organization and site. While diverse approaches have been developed, most of them can be grouped into seven basic areas as discussed below.

Provide employees with information. Because of the diverse, semi-autonomous climate in which most research is usually conducted, development of an organizational mind set becomes one of the first and most important waste reduction opportunities for R&D organizations to pursue. Without such a mind set, further efforts may have little or no affect without constant reminders and reviews. Through a series of internal seminars and presentations, possibly coupled with letters and brochures, employees can be provided with detailed information on why reduction is important, the cost-saving potential and the basic rationale for such a program. Here is where one tries to create the desired thought process.

This information should review the possible methods to achieve reduction, and encourage attempts at innovative approaches, ideas, and solutions. In order to garner the maximum amount of individual interest and support for such an effort, it's important to emphasize what's in it for them. Approaches which have been met with success suggest 1) there will be reduced operating costs, thus freeing the budget for other work in his or her area and 2) the development of new or modified processes for the competitive advantage of the organization and the personal recognition that could result. This second aspect will be discussed in more detail later in the paper.

WASTE REDUCTION IN THE R&D INDUSTRY

Waste reduction is becoming an increasingly important aspect of virtually all industrial organizations, large and small. Real incentives for reductions are provided by disposal cost increases on the order of 25% to 100% per year and by potential long-term waste generator liabilities associated with waste disposal site cleanups. When combined with regulatory pressures, shrinking disposal options such as the recent EPA land disposal bans and by minimization certifications, there are significant driving forces to reduce the volume and/or hazardous nature of our wastes.

This paper presents practical experiences with waste reduction for R&D organizations and shares some of the difficulties that appear to be rather common among those organizations which have made attempts at reducing their wastes. Major areas of discussion are:

+ The unique characteristics of experimental units,

+ Waste reduction opportunities and experiences,

+ Tracking and reporting of R&D waste reduction efforts, and

+ A suggestion as to the future challenge for the R&D industry.

The information presented reflects a compilation of personal experience as well as that of my counterparts in other organizations, based on our mutual contacts, activities and discussions. Thus, individual details should not be considered to be automatically applicable to all companies or organizations, as each will have their own situations for which success or failure may be realized based on a variety of factors.

Unique Characteristics of Experimental Units

Recent conference presentations and journal articles, even the Office of Technology Assessment Report on serious waste reduction, have provided a significant amount of information on the economics, technologies, and even operational changes for waste reduction in manufacturing facilities. Unfortunately, little if any of this information is of much use in the research and development environment because of the unique characteristics of experimental units. Waste reduction during research and development is helpful not only to the specific research operation and site, but also to the operating/production facility which may utilize the new or modified process units resulting from that research.

The three unique characteristics of experimental units - diversity, variability, and originality - all suggest that the waste reduction opportunities for R&D organizations may be quite different than those for manufacturing sites:

Two vital pieces to the ultimate success of this opportunity are the inclusion of executive management in the program and obtaining their support and commitment for all facets of the activity. They will be able to supply the loud and clear message that they view waste reduction as an important, worthwhile effort for all employees to take the time to pursue. Without such support and commitment, any efforts are likely to be difficult to implement and yield only marginal results.

Some of the surest and least expensive opportunities for reducing waste are those which keep non-waste from becoming waste. There are several ways to accomplish this, three of which are discussed below.

Purchase smaller-sized units of stock chemicals. The stocking of smaller sized units of stock chemicals is more of a materials handling consideration than a technical consideration. This approach involves making available the smallest sized units of the chemical necessary for an experiment. Instead of stocking only gallon-sized containers of a material, consider stocking additional quantities of quart or pint-sized containers. While the initial cost for the chemical purchase may be higher, in many cases disposal costs for unwanted remainders often exceed the purchase cost. Thus, the increased purchase cost will be more than offset by the reduced waste cost. Of course, in certain instances larger unit sizes are truly needed and justifiable - these can be handled on an individual case-by-case basis rather than through the stockroom supply system.

Restock unopened materials. A second method to keep non-waste from becoming waste is to restock unopened stock chemicals. Research scientists and engineers who possess unopened stock chemicals should be encouraged to return these materials to the stock or supply room instead of discarding them. In this way, others may be able to use the materials which might otherwise become wastes though each container may have to be dated to determine if its usefeul shelf life has been exceeded. If possible, the restocking of opened stock chemicals is also an alternative. However, in research work this is seldom practical due to the high quality material required (or in some cases merely desired) by each researcher and their uncertainty about the quality of the material remaining in the container.

Create an internal material exchange. Perhaps the largest opportunity for keeping non-waste from becoming waste exists in the creation of an internal material exchange or "classified ads" system to keep surplus non-stock or open stock materials from being discarded unnecessarily. This can be done in a variety of techniques. An organization might develop a multi-accessible computer network or organize a manual system utilizing a trained contact person.

If conducted through a computer, entries can be logged into a data base by research scientists and engineers to create a chemical exchange program. More and more organizations are creating a chemical inventory system as a part of their Right-to-Know and SARA Title III compliance programs, so the exchange portion would represent only a small incremental cost to set up. If conducted through a manual system, researchers can call a contact person who keeps entries indexed by file cards or a dedicated personal computer.

Information can be distributed via a weekly posting, newsletter, or hotline telephone number.

Regardless of the type of information system used, it's important to refer to the materials by their chemical abstract number due to the various synonyms used for the same material. In one instance, more than twenty different entries were found for exactly the same chemical, largely due to different manufacturers' commercial product names. Also, each system should have "available" as well as "wanted" listings which contain information such as the person owning or wanting the material, the location, amount and grade of material, the size of the container, and the date when it is desired or will be available. It would be important to purge the entry information periodically.

Allocate disposal costs. Allocation of disposal costs is perhaps the greatest single, effective tool to heighten individual awareness of waste reduction. Often the researcher and the individual line organization is not aware of the costs of disposing the wastes from their subject research. One very effective opportunity to encourage such consideration is the allocation of waste disposal and handling costs as a separate line item internally billed directly to the account of the generating project or organizational unit. When such costs show up as an accountable expenditure which the generator must budget and track throughout the year, additional attention is directed to them. In some situations a revised accounting system may be required for separate billing on such a basis.

Essential to the viability of this opportunity is the accurate identification of the generating lab, division, or project on each container's waste identification form. The disposal and handling cost of each container of waste then can be back-charged to the generator as part of his or her total project budget. Experience has shown that in a research environment frequently the individual cost of each container cannot be determined. In those cases some type of prorated share of the waste disposal costs for similar materials can be distributed among the generators.

This cost allocation concept has the potential for being extremely effective in developing the generator's awareness to the cost of waste disposal and the saving that may be realized to his or her organization by reducing waste. As long as disposal costs remain a hidden budget item, visible only to administrative or operational personnel and not to the individual research project or generator, specific attention to this type of cost will not be achieved to the maximum extent. Attention brought about by this form of awareness is also beneficial in maintaining the desired mental attitude of each employee.

Treat at the source. Treatment at the source has been emphasized in most of the published information applicable to R&D activities. The American Chemical Society's pamphlet "Less Is Better" stresses this as a primary opportunity when discussing research applications, as does the Duke University Medical Center's document, "Management Strategies and Technologies for the Minimization of Chemical Wastes from Laboratories". While there are some advantages to this approach, there is a significant caution which should be given careful consideration before proceeding - there may be regulatory implications with "treating" hazardous wastes without an appropriate permit. Authorities such as EPA, the respective state agency, and possibly an environmental lawyer should be consulted prior to actively pursuing this opportunity.

Conduct environmental audits. An environmental audit program for experimental units can provide the opportunity for necessary issues to be considered during the project or unit design phase, prior to construction and operation. Such a review is most easily implemented if included within an existing safety or budget review procedure. While including environmental considerations, it can also be used to include industrial hygiene aspects, which frequently address parallel issues.

There are several ways to address this opportunity, the specifics of which need to be formulated to meet the needs and objectives of the individual organization. One technique incorporates the project review within the regular planning and budget process. Figure 1 shows how a review system, which includes safety, environmental, and industrial hygiene aspects, can be structured. Regardless of the exact flowplan, the central concept is to assure that all suitable work is reviewed and that there is a cross-check at some point in the process. In this case, the cross-check is the requirement that the project review must be completed before the budget estimate can be released.

A copy of the environmental portion of an experimental unit review form is presented in Figure 2. The purpose of a form such as this is not to solicit all applicable information on the unit or its operation. Rather, it is to develop enough information so that a knowledgeable person can determine if follow-up consultation is required. For example, based on the rather simple information it may appear that an air pollutant emissions certificate is needed or that the site wastewater treatment plant cannot handle the type or amount of effluent. While the requested information may not always be readily available, the form provides for a consistent set of questions for which answers ought to be obtained for the benefit of the organization, the research person, and the environment.

Note that there are two items relating to hazardous waste generation and minimization. If nothing else, the opportunity for the researcher to respond to the requested information may get him or her to think about their work in a slightly different light, so as to include proper waste handling and waste reduction as a part of their daily research objectives. Responses such as "according to company procedures" or "as usual" usually indicates that the researcher doesn't know and further follow-up by the site environmental contact may be necessary.

A key advantage to an environmental audit at this stage of the research work is that such considerations can be addressed at a time when cost-effective solutions can be incorporated easily. For example, a unit was proposed for the separation of rubber polymer from a solvent base. The original design had a simple stripper which vaporized and vented much of the solvent, with the remaining wet residual polymer to be handled as a hazardous waste liquid. By considering air emissions and waste disposal, minor modifications reduced hydrocarbon emissions by 90% and upgraded the waste stream such that virtually 100% of the polymer was recovered and most all the solvent could be recycled back into the process. Not only did this reduce hazardous waste generation but those design improvements had a pay out time of only about 2 months due to reduced waste disposal costs and feed solvent purchases. It will also greatly enhance the profitability of similar units in operating plants.

As such, units which have environmental solutions or improvements incorporated into their designs have distinct advantages. Several corporations have formal programs for their operating plants - 3M Company's Pollution Prevention Pays program is perhaps the best known and documented. However, I've not been able to find any published literature suggesting organized efforts to apply such concepts to R&D activities.

Tracking And Reporting Of R&D Waste Reduction Efforts

A key element to any serious waste reduction effort is the tracking of how well your program is doing. This is usually done by comparing waste generation and costs from one time period to another, with figures often normalized to a common factor such as throughput, production, or sales. Reports are developed for internal evaluation and/or submitted to regulatory authorities pursuant to applicable hazardous waste regulations.

Unfortunately, problems have been encountered with the tracking and reporting of waste reduction efforts by the R&D industry, largely due to the inherent variability of each organization's activities. Tracking and reporting accurate, meaningful results is no easy task. Project initiation or expiration impacts each year's types and quantity of waste. The initiation of a single large unit can overshadow current waste generation quantities and wipe out true reduction successes. Conversely, an expiration of one or two key projects can inaccurately show up as a significant waste reduction success.

Laboratory cleanouts can also distort an individual year's generation, especially in a smaller organization or if cleanouts are not conducted frequently. It is not uncommon to see an increase of 10%-50% in an annual reporting quantity due solely to a site-wide cleanout.

Part of the difficulty in accurate tracking and reporting goes back to the difficulty in determining how much waste is being generated since such determinations are not as straight forward as in a manufacturing plant. Research wastes are often accumulated in a "lab-pack", which is a drum or box of several individual but compatible containers of waste. A weight basis for determining the amount of waste usually includes the glass or metal containers, cushioning material, and the overall drum or box. Since in many cases the major weight is the individual and overall packaging, the actual weight of the waste material is difficult if not impossible to determine. Also, true weight reductions in lab-pack wastes may be overwhelmed by the year to year variations experienced due to project initiation/expiration and cleanouts.

Converting to a mixture of weights and volumes to report the various waste streams can alleviate this somewhat, particularly if the much heavier, drummed liquid wastes are reported separately from lab pack wastes. However, the routine administrative tracking and reporting then becomes even more cumbersome as most wastes would then require at least two reporting parameters and many lab-pack liquids will still need to be shipped and reported under the DOT "solids" designation. It is clear that each organization should investigate the associated advantages and disadvantages in light of their own particular waste streams and set of circumstances.

The use of a normalization factor in reporting waste generation and reduction is instrumental in generating useful data for internal or regulatory agency study. NJDEP recognized this and incorporated the concept into last year's annual reporting requirements for hazardous waste generators. This raised the question of what would be an appropriate factor for the R&D industry? Factors such as production, throughput and sales were clearly inappropriate.

Several factors such as research dollars, number of research units, number of researchers, among others are somewhat indicative of research activity and should have at least a casual relationship to waste generation. While research dollars may be the most accurate normalizing factor, often it is proprietary information and not available for release. Research units can be operating or idle at almost any given time or duration. Also, not all units are the same - a wet chemistry unit could not be comparable in waste generation to a semi-works pilot plant.

Thus, the total number of on-site people appears to be a suitable, albeit not perfect normalizing factor. For intensive research sites, it should be close to the total research population and somewhat indicative of site activity and waste generation. For less intensive office/research sites, this would be less sensitive to annual swings and variations in individual research programs. However, as the resultant waste per person value will tend to be much lower at this second type of site there is an inherent difficulty in comparing waste generation rates between the two types of sites.

The Future Challenge For R&D Organizations

A few short years ago the first industrial waste reduction efforts were directed toward alternate disposal strategies, usually away from land disposal and final treatment or incineration. Lately, the thrusts have been directed toward changing in-plant procedures, equipment, or feedstocks. The future direction for industry may be to go further upstream, to address waste reduction before the plant or process is designed and constructed.

Thus, as an integral part of the total waste reduction effort, the R&D industry faces a rather formidable future challenge - to develop new or modified processes which incorporate waste reduction into their basic, intrinsic designs. This probably has the potential to provide the most significant, long term reduction in industrial waste generation by ensuring the amount or hazardous nature of any waste is reduced to the minimum level possible, hopefully even to the point of elimination in many cases. By working with the process designers, especially those working on the research or pre-commercialization activity, the concept of how to reduce wastes can be included within the chemistry and engineering of the process. The audit technique discussed earlier can be an instrumental tool in addressing this challenge.

An effort such as this has advantages which may be more clearly understood by others less familiar with hazardous waste issues if put into terms familiar to them. First, it has the potential to result in increased competitive advantage for the company or organization. Waste reduction of 10%, when put on a large scale commercial basis, yields substantial savings on waste disposal costs. When that 10% is compounded by annual disposal cost increases of 25-100%, it becomes even greater. Such reductions in a unit's operating cost can make a process a star money-maker if the competition has operating costs which still include waste disposal. Alternately, these reductions can change what might otherwise be a non-competitive product improvement into a highly competitive one. This aspect is especially important in mature industries, where significant industry-wide process improvements may not otherwise be available.

Second, recognition for both the personnel and the organization can come from such an effort. Personnel can get recognized for contributing to the success of the organization. Patents, awards and promotions are but a few of the possible resultant rewards. For the organization, it can make their R&D more valuable to the commercial sectors it supports. That can bring in either more work or better supported work into the organization. Of course, there are also the public affairs aspects which can be used to promote the favorable public image every organization strives to achieve.

Summary

The uniqueness of experimental units requires unique approaches to waste reduction. Approaches common to manufacturing plants are seldom applicable or effective in the R&D industry. Nevertheless, there are several waste reduction opportunities available to R&D organizations, many of which are relatively simple and inexpensive to initiate. An environmental audit during a project's design phase can provide a forum to discuss waste reduction, along with a variety of other environmental issues.

Waste reduction tracking and reporting are difficult due to the nature of R&D work and the types of wastes generated. Accurate, meaningful comparisons between different organizations or across time frames require more than a cursory investigation. The future challenge for the R&D industry is to develop new or modified processes which incorporate waste reduction with their inherent designs. Besides long term waste reduction, increased organizational competitiveness and personal recognition are but two of the rewards which can result from such an effort.

Steven C. Rice, P.E.
Corporate Ecology
BASF Corporation
November, 1987

FIGURE 1

FLOW PLAN FOR EXPERIMENTAL UNIT REVIEW FORM

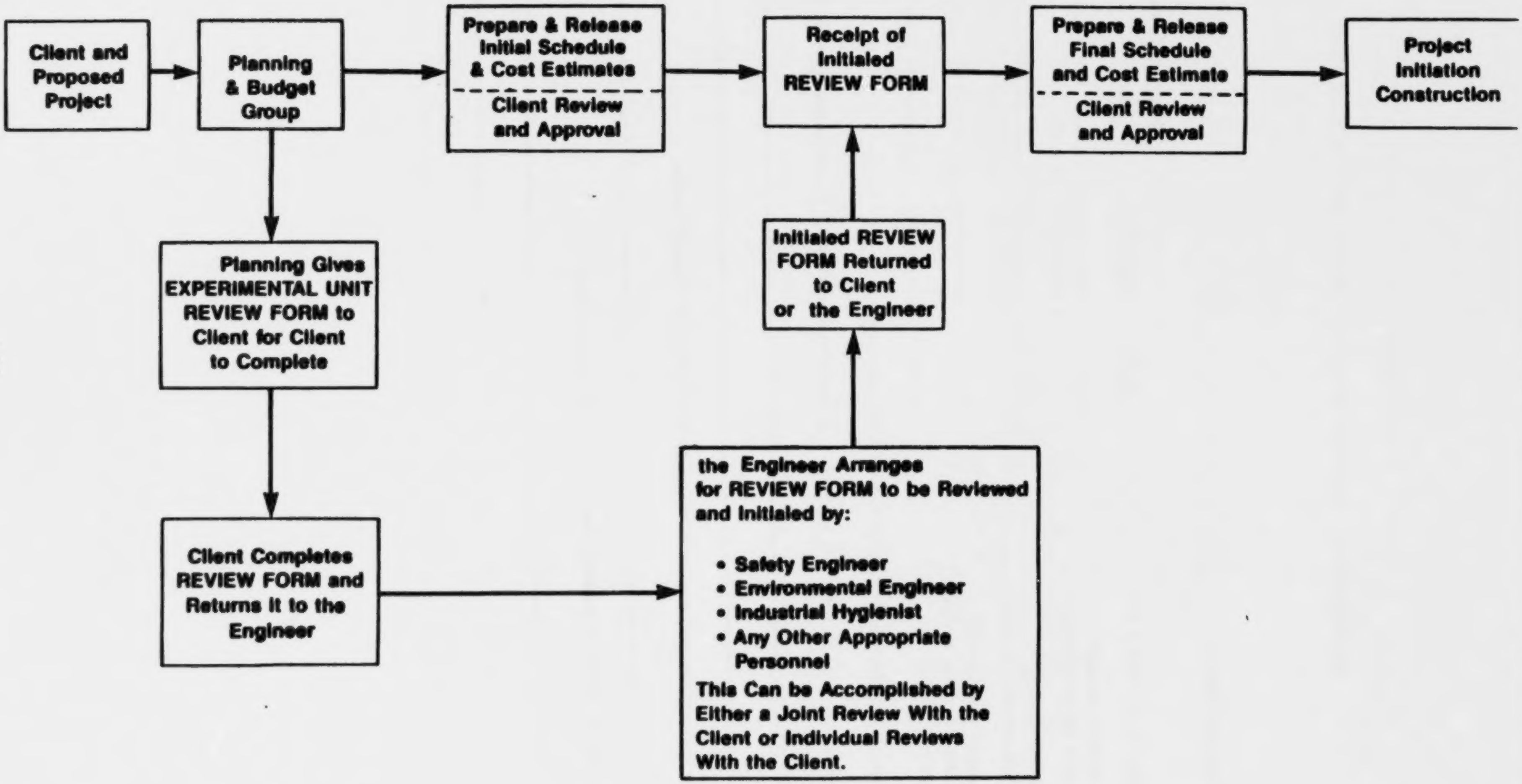

Client and Proposed Project
Planning & Budget Group
Prepare & Release Initial Schedule & Cost Estimates
Client Review and Approval
Receipt of Initialed REVIEW FORM
Prepare & Release Final Schedule and Cost Estimate
Client Review and Approval
Project Initiation Construction
Planning Gives EXPERIMENTAL UNIT REVIEW FORM to Client for Client to Complete
Client Completes REVIEW FORM and Returns It to the Engineer
the Engineer Arranges for REVIEW FORM to be Reviewed and Initialed by:
• Safety Engineer
• Environmental Engineer
• Industrial Hygienist
• Any Other Appropriate Personnel
This Can be Accomplished by Either a Joint Review With the Client or Individual Reviews With the Client.
Initialed REVIEW FORM Returned to Client or the Engineer

FIGURE 2

ENVIRONMENTAL SECTION OF EXPERIMENTAL UNIT REVIEW FORM

F. Environmental Concerns

			Maximum Emission Rate	
Will there be any potential for:	Yes/No	Material(s)	per hour	per day
• air pollutant emissions? (includes use of vent lines)			(lbs)	(lbs)
• wastewater discharge? (includes overflow or release to sewer)			(gal)	
• ground/soil contamination? (includes spill during operation or material handling)				

Are there any emission control devices anticipated in the unit's design?

☐ exhaust filters ☐ cyclones ☐ scrubbers ☐ liquid/vapor separators ☐ other emission control devices?

If so, describe:

Describe how wastes (unused feeds, samples, and products) will be identified and handled.

Describe how the volume or hazardous nature of the wastes can be reduced.

Zero Discharge, Zero Pollution,
and Source Reduction

Presented by
Robert H. Elliott, Jr.
President
Zerpol Corporation
Hatfield, Pennsylvania

Zero Discharge, Zero Pollution, and Source Reduction

by Robert H. Elliott, Jr.

Zerpol® Corporation, Hatfield, Pennsylvania 19440

Two hundred years ago the industrial revolution began. In this century we have a new kind of revolution - environmental. The first revolution improved our quality of life. The second is destroying it. In 1950 the Chesapeake Bay started to decline and with each year the rate is accelerating. Our streams, lakes and rivers are being polluted on a daily basis. Some scientists say our aquifers cannot be saved, but we must look for that reversal.

Let me tell you one way that we can stop this trend - zero discharge/ zero pollution. For such a system to be successful it must be cost effective. A plater wants to see a waste treatment system after it has been running for three, four, five years. So many equipment companies have gone bankrupt and, unfortunately, taken some platers with them in the first year. Even systems that continue to operate have upsets and with increasing frequency in the second and third year.

Zero discharge is simply cementing over the drain so that no wastewater, treated or untreated, can leave the plant. Of course, we build the system first... a quality system, one that will take any chemical such as cyanides, chelates, and electroless copper or nickel and treat it with precision even if there is an unexpected slug, no environmental spills, no fines. The other consideration for a quality system is leaving room for expansion. In 1981 we built a complete new shop for a 20 year old business with the assurance that the owner could double his plating operations. He moved in and doubled his business the first year. In 1985 he doubled his volume again and without any modification of his Zerpol system.

Papers have been given on our patented Z.D. system and there are reprints here telling how the system works. I will discuss the system briefly and then move on to zero pollution. The process is a batch operation with chemical destruction of cyanide and hexavalent chrome. Chlorine is never used in any form. The final adjustment is pH to a level of 9 to 10 and the tank is left to settle overnight. No flocculating agents are used. The crystal clear water is pumped to the clear water storage tank and the sludge to a sludge concentrator. Over a period of time the suspended solids will increase from 1/4 percent to as high as 10 percent. I will come back to the alternatives for sludge control during the discussion of zero pollution and again on source reduction.

Once the metal hydroxides settle in the sludge concentrator the clear water is decanted off and is used to dissolve the treatment chemicals (chrome reductant, acid, alkali etc.) for the next batch. Of the many systems built since 1979 the size has varied from 6000 gallons to 250,000 gallons. A typical 20 man shop may require a batch size of 25,000 gallons. Of course, the metals plated may vary the amount of rinsing as does rack plating versus barrel plating. The normal amount of sludge is, say, 500 gallons and the clear water may be 500 gallons. After the pumped sludge settles the clear water may be 800 - 850 gallons.

The recycling of the water from the sludge concentrator has several advantages. The sludge remains in the system and, therefore, is not subject to the 90 day storage rule. Only when the concentrated sludge (10%) is removed, does the clock start running. The mixed metals go directly to a treater or preferably to a smelter. They can also have an intermediate step of a filter press. Another combination is to filter press and dry. A third method is to dry the metal hydroxides directly in a 400° F. oven.

The description of the sludge concentrator is complete and now the salts concentrator will be discussed. The clear water contains salts, such as sodium chloride, sodium sulfate and sodium nitrate and on occasion potassium salts. In order to remove these economically, we use the company boiler. The salts typically enter the boiler at 6000 ppm and concentrate in the blowdown. From the blowdown pan the salts are pumped to the salts concentrator. A small fan pulls off the moisture laden air (about 130° F.) and sends the condensate (1 - 5 ppm dissolved solids) to the same tank as the boiler condensate. Again, the 90 day storage rule does not apply until the salts, which contain 10 - 15 ppm of various metals, leave the system.

Zero Pollution

In order to achieve zero pollution from a plant, the three separations - organics, salts and sludge must be dealt with in a very precise manner. Oil (organics) may enter the plant on steel parts to be plated, or as in the case

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of the first installation of the Zerpol concept in 1979, about half a truckload of waste oil was generated each month due to punch presses and elaborate forming devices. At first, the oil was burned but the methylene chloride was too high and started to attack the fire side of the boiler. In addition we were not sure of a quality burn. There were no P.C.B.s present and the temperature in the furnace was 1800° F. The methylene chloride was less than 1000 ppm. It was contemplated that the methylene chloride and a lesser amount of trichloroethylene could be separated but at the same time, the idea occurred why not separate the various oils and have them reprocessed. This was accomplished and at a very substantial savings. The remaining oil was so small that it was shipped with the metal hydroxides to a waste treater. Normally, oil or organics are sent to a certified burner that is approved by E.P.A. or the individual state. Reclaiming of the oil, of course, is a source reduction.

The next item to remove so that we do not harm the environment is salt. Many managers, platers, scientists, et al, ask why treat sodium chloride or sodium sulfate as a hazardous waste? Sodium is bad news for heart patients and up to recently limits were not enforced. In some areas the limits are 250 mg/l for each salt. A continuous discharge system may dump 1500 to 3000 mg/l on a daily basis and such high dosages flowing into our streams and aquifers are highly detrimental. A few months ago we installed a zero discharge system in Florida and the president of the company now states that they have better water in their plating shop than in their drinking fountains, about 10 ppm total dissolved solids. When a truckload of salts is accumulated and the concentration reaches 30 - 40 percent, it is either mixed with the sludge and dried to 100 percent hard cake or transported to a salts treater, such as Du Pont Chambers Works in New Jersey or made into caustic soda and sulfuric acid in the job shop. This latter method is primarily for anodizers where the bulk of the raw materials are sulfuric acid and caustic soda. No salts leave the plant and the traces of zinc, copper, iron, etc. in the caustic cell are removed to the sludge concentrator.

The final hazardous waste to remove from the closed system are the metal hydroxides. The amount may vary from one truckload (40,000 lbs.) of 10 per cent solids per year to one truckload of hard sludge (100 per cent dry) a month or a range of 4000 pounds to 480,000 pounds. A typical 20 man shop rack plating copper, nickel and chrome on steel and zinc die castings will yield about 12,000 pounds of dry sludge and salts.

The best metal sludge disposal method is smelting and it is the most economical. Our company has been working with a primary mining company near our plant in eastern Pennsylvania for seven years. At first the truckloads were liquid but now the sludge must be dry cake. It must also be 14 percent zinc. The waste is fired at 2500° F. for 30 to 40 minutes. The zinc goes off as a gas in the range of 600 - 1000° F. The cadmium, lead, mercury and other volatile metals go off as gases, but the temperature continues to climb and for a very desirable reason. The iron, copper, nickel and chrome fuse into an inert mass. Leachate tests on the cinders show below detection limits for all metals except iron and calcium. Interestingly enough complete dissolving of the cinders showed iron, chromium, copper and nickel but no zinc. Zinc ore samples from many parts of the country could not come close to passing the E.P.A. leachate test.

People try to point out that we do not have zero pollution even after they have seen a half dozen systems functioning perfectly. Part of the picture is how we define pollution. A daisy in the middle of the lawn is a weed, but hundreds along the edge are a pretty border. Lead in a mine is valuable, but lead in our water is a pollutant. My personal conviction of success in fighting pollution will be borne out when the incidence of cancer declines dramatically.

Up until now the total toxic organics (TTO) have not been mentioned. Visualize a kiln 250 feet long and 12 feet in diameter at 2500° F. No TTO's could possibly make that trip. It is well documented that organics adhere to sludge.

Actually TTO's are destroyed in the Zerpol closed system and tests show no detection of the 28 priority pollutants in the volatile section for two plants operating for three years. These same two plants were measured again after another three years and again the data showed below detection which were levels about 1 part per billion. Perhaps someday instruments will measure molecules per liter because that is the level of concern, but if we capture everything (TTO's), we can wait for the instrument.

On the other hand, if a continuous discharge system after chlorination discharges to a sewer or stream, it will probably be 2000 to 4500 parts per billion of TTO's. Most company presidents are put in a state of shock at our reports and we encourage them to get independent reports. Companies will follow "solvent management rules" and they feel comfortable until they receive one of our reports. It is the generation of nine or ten TTO's, especially chloroform, when chlorine is used to destroy the cyanide present. E.P.A. rules require the use of chlorine when discharging. If no cyanide is present, the organics move on to the P.O.T.W. where chlorine has a second opportunity to generate carcinogens.

Source Reduction

With total control of end-of-pipe (over two billion gallons without a fine or spill), we turn our attention to source reduction. High quality distilled water is available from the boiler and at a cost considerably lower than the city tap water. A triple counterflow is placed after a nickel plating tank. The evaporation rate is 80 gallons per day from the nickel tank. A restrictor is placed on the third tank to equal the 80 gallons and meter in distilled water. A small air pump or sealless magnet coupled pump is used to move the nickel solution back into the plating tank. The cost of the pump is $100 and the stainless steel counterflow may be $1500. The operating cost is less than a hundred dollars per year. In sharp contrast reverse osmosis, evaporators, ion exchange and atmospheric evaporators cost $10,000 to $20,000 per year to operate and substantial amounts to install. There is another aspect about atmospheric evaporators besides the $10,000 fuel bill, which is that the evaporator throws TTO's into the atmosphere.

For chrome plating it is suggested that a four or five stage counterflow be used. Usually a chrome bath is operated at a lower temperature (120° F.) than nickel. We like to see a temperature of 135° F. which will double the evaporation rate. To evaporate one gallon of water requires about 8000 BTU's. The evaporation rate is one pound per square foot at 120° F., two pounds at 135° F and four pounds at 150° F. or about 1/2 gallon. A 4' x 10' tank of nickel solution would evaporate about 20 gallons per hour with rocker arm agitation and about 50 percent higher for air agitation. Conservatively, this is more than enough water loss to run a triple counterflow. I would be remiss if I didn't mention another source reduction method for nickel that is very economical to run.

It is precipitation of the nickel in the first and second stage of a three stage counterflow at a pH 9. The nickel rinses are continuously filtered (30" cartridge type) and when the cartridges are fully loaded, they are placed in sulfuric acid. The same acid used to adjust the pH of the nickel bath. Some platers report they use a carboy a week for adjustment and this is more than adequate to redissolve the nickel hydroxide. Distilled water is used in the third stage and the result is very pure nickel sulfate.

The three, four, five stage counterflow principle can be applied to any of the common plating baths except precious metals. In general, the recovery costs of the various metals is less than 10 percent of their market value versus two to three times their market value for other methods and economics is the name of the game.

Some companies will justify the additional expense by claiming the tremendous savings in waste treatment. This is not true. With total control of the end-of-pipe we can easily measure the amount of nickel, copper, zinc or other metals. Here is a case history of a job shop with sales of $2,000,000 per year. They had a continuous discharge system for six years, which cost $142,000 per year and now they have a Zerpol zero discharge system, which costs $39,200 per year average to operate. Their sales varied but the above figures are based on $2,000,000. At this point in time (Fall 1987), they have completed six years with zero discharge, which matches the six years with continuous discharge. There were many fines with the old system and none with the new system. The state of New Jersey sent many people to show how it should be done and the owners were very pleased and proud of what they were doing for the environment. They are currently being televised on Nova as the company that is doing something about our deteriorating environment.

We mention this case history to illustrate a point. The electroplater had two percent zinc in his sludge even though he did not zinc plate. He plated copper on zinc die castings and some zinc dissolved in the cleaners and pickling acids. In order to ship the sludge to the smelter, it was necessary to get the zinc content up to seven percent. Most of the sludge was iron. The plan was to recover all the nickel and about half the copper to bring the zinc to the magic seven. It was a shock to learn that half the nickel was still in the sludge. At the same time, the smelter announced that the zinc content must be at least fourteen percent and they were receiving so much platers' "ore" that they shut down their own mine in New Jersey.

Meanwhile a zinc plater in Ohio was very pleased with the smelting operation. He installed a Zerpol system and a filter press under our direction and he was actually getting a substantial rebate. Here is the story. About every five weeks a truckload is shipped and if the zinc content is fourteen percent, the price is $1200, but if the zinc content is high, the price can be as low as $500 plus freight. Is there any doubt that this is the cost-effective way? Do not think of this as a zinc haulaway, but one that takes the "inert" dirt in the cleaner tank, the inseparable metals in the pickle, the hard to handle strippers and the daily post treatment dumps. Just as Zerpol gives you end-of-pipe perfection, smelting gives you inert fused nuggets.

In summary, we must give the plater total answers, practical, econonical ones. If plating becomes too expensive, industry will turn to painting. Therein lies the danger of toxic organics. If source reduction becomes too tough, the plater will turn to dilution and a waste of our most important resource - clean water. Our solutions must be permanent answers for the eons of time to come.

A Waste Reduction Audit Workshop for the Metal Plating & Finishing Industry

Presented by
Robert H. Salvesen, Ph.D.
S&D Engineering Services, Inc.
Metuchen, New Jersey

1. Introduction

This paper will cover the following aspects of the metal plating and finishing industry:

- Solvents used
- Source and Nature of Waste
- Reclamation Options
- Waste Reduction Practices and Examples

A paper entitled "Waste Minimization Alternate Recovery Technologies" (1)* which appeared in 1986 provides an excellent summary of recovery and recycling technologies for metallic sludges and aqueous systems used in the industry.

Proper management of the organic materials used can result in significant reduction in the volumes and costs of wastes to be disposed. In order to accomplish these objectives, it is helpful to get a better understanding of what materials are used, and handling, treatment, recycling and disposal options that are available.

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* Numbers in parenthesis indicate reference given at the end of this paper

2. Types of Solvents and Other Materials Used

The major used solvents generated by the Metal Plating and Finishing industry may be classified as follows:

- General purpose cleaners
- Carbon removers and paint strippers
- Halogenated Solvents

A discussion of the types of materials used follows:

2.1 General Purpose Cleaners

Hydrocarbon solvents are most commonly used for this purpose. They may be called by different names, but are generally very similar in properties. In the petroleum industry they an designated as mineral spirits or naphtha. However, some products may have additives which appeal to individual shops and are preferred over other products. For example, some products may contain the following types of additives:

- Detergents - these can provide better penetration of oil and grease on automotive parts and also allow water washing for cleanup.
- Lanolin - this and other similar additives may be added to leave a residue on the skin to reduce skin irritation.
- Color and perfumes - to provide a recognizable more attractive product.

There can be some real differences in the basic properties of petroleum products used for these purposes, however, the industry usually does not distinguish among them. For example, the higher the aromatic content of the mineral spirits, the better the solvent power.

Products supplied by service organizations, such as, Safety-Kleen and others are general purpose hydrocarbon based cleaners.

Other solvents used are noted below along with brief comments:

- High flash naphtha - this is a petroleum hydrocarbon with a Flash Point above 140 F to provide an added safety factor. All petroleum general purpose cleaners such as those noted above should have a Flash Point of 100 F minimum.
- Odorless solvent - some shops have been found to use an odorless paint thinner for general purpose cleaning. While this solvent smells nice and can do a good job, it takes more "elbow grease" to remove oil and grease and also costs more.
- Safety solvents - these may be a High Flash naphtha such as noted above, or a blend of hydrocarbon and chlorinated (i.e. Methylene chloride) or Freon solvents. Such solvents can serve a very useful purpose, and may be required in some applications. However, solvents containing chlorinated or Freon solvents are often not desired for some uses because of the concern for corrosion if left on components. Freon solvents are less of a concern than chlorinated solvents.
- Ethyl Acetate - This is a pure chemical and is used either in dip tanks or vapor degreasers. It is a highly volatile and flammable solvent that is generally being replaced by TCA (Triehloroethane).

2.2 Carbon Removers and Paint Strippers

While these products differ in some respects, they are similar in that they generally contain two or more of the following:

- Hydrocarbons
- Chlorinated solvents (generally methylene chloride)
- Phenolic compounds
- Alcohols, esters, ethers
- Colors, detergents, and odorants

These are powerful solvents and a wide variety of formulations are available especially for removal of different types of paint.

2.3 Halogenated Solvents

Halogenated solvents used include a variety of chlorinated solvents and Freon 113. Several popular chlorinated solvents have been designated as potential carciniogens by EPA and thus the major products still in use are:

- Methylene chloride
- Trichloroethane (TCA)
- Freon 113

Reference has been made above to the use of methylene chloride in cleaners and strippers. This material and TCA are also used to clean electrical parts. Freon 113 and TCA are also used for precision cleaning of bearings. The major benefits of these halogenated solvents are:

- High solvent/cleaning power
- Rapid evaporation rate (low residue)
- Non-flammability

2.4 Other Materials

Aqueous based emulsion and alkaline solutions are used for a number of stripping and cleaning applications. A wide variety of detergents can be used for cleaning purposes, which generally contain phosphates and/or organic compounds. These may be used in conjunction with steam or hot water systems.

Alkaline solutions may contain either sodium hydroxide (caustic soda) or organic amines. These are generally used in dip tanks and must be handled by trained personnel, since they can cause severe skin burns and are very toxic.

3. Generation and Properties of Used Materials

3.1 Used Solvents

Used solvents may be defined as any used organic fluid contaminated as a result of use for cleaning, thinning, or use as a solvent, antifreeze or similar purpose. Used solvents are generally volatile in nature. They include hydrocarbons, halogenated hydrocarbons, oxygenated hydrocarbons and mixtures of these materials.

Used cleaning solvents are generally produced by spraying, physical or vapor washing, dipping and other means.

Typical properties for used hydrocarbon, TCA and Freon 113 solvents are given in Tables 3-1, 2 and 3 along with properties of virgin or reclaimed solvents. Properties for virgin and reclaimed solvents should be essentially the same and can generally be accomplished with available resources. Ethyl acetate is a pure compound with a boiling point of 171°F.

Table 3-1

Typical Properties of Used, Virgin or Reclaimed Hydrocarbon Cleaning Solvent

Test	Test Method	Properties For		
		Used Solvent	Virgin or Reclaimed Hydrocarbon Solvent	Virgin or Reclaimed High Flash Solvent
Flash Point, TCC,F	ASTM-D-56	<100-140	102-110	140 min
Distillation,F	ASTM-D-86			
IBP		150-330	315-330	355-360
10%		150-340	320-340	360-370
20%		170-340		
30%		300-345		
40%		320-350		
50%		325-350	325-350	365-380
60%		330-370		
70%		340-390		
80%		350-400		
90%		400-600	330-365	375-390
FBP		Above 500	350-400	415 Max
Residue		30 Vol% (Max)	2-5 Vol%	2-5 Vol%
Chlorine Content		<0.1	<0.1	<0.1
Water, Oil & Sediment%	ASTM-D-95	2-20	<0.1	<0.1
Appearance	Visual	Brown/ Black	Clear/ White	Clear/ White

Table 3-1

Typical Properties of Used, Virgin or Reclaimed Hydrocarbon Cleaning Solvent

Test	Test Method	Properties For		
		Used Solvent	Virgin or Reclaimed Hydrocarbon Solvent	Virgin or Reclaimed High Flash Solvent
Flash Point, TCC,F	ASTM-D-56	<100-140	102-110	140 min
Distillation,F	ASTM-D-86			
IBP		150-330	315-330	355-360
10%		150-340	320-340	360-370
20%		170-340		
30%		300-345		
40%		320-350		
50%		325-350	325-350	365-380
60%		330-370		
70%		340-390		
80%		350-400		
90%		400-600	330-365	375-390
FBP		Above 500	350-400	415 Max
Residue		30 Vol% (Max)	2-5 Vol%	2-5 Vol%
Chlorine Content		<0.1	<0.1	<0.1
Water, Oil & Sediment%	ASTM-D-95	2-20	<0.1	<0.1
Appearance	Visual	Brown/ Black	Clear/ White	Clear/ White

Table 3-2

Typical Properties of Used, Virgin, or Reclaimed TCA Solvent

		Properties For	
	Test Method	Used Solvent	Virgin or Reclaimed Solvent
Flash Point, TCC/F	ASTMD1310	None	None
Distillation, F	ASTMD1078		
IBP		149+	171
50%		190- 250	
FBP		500+	190
Residue		10-40%	10 ppm (Max)
Water Content, ppm	16822A	1-5%	100 ppm (Max)
Appearance	Visual	Black	Clear/White
Specific Gravity @ 25 C	ASTMD2111	1.15-1.3	1.317-1.324
Acid Acceptance No. mg NaOH	16822A(*)		0.20 (Min)

(*) Need to check supplier for details of tests to be run and additives required to reformulate reclaimed solvent.

Table 3-3

Typical Properties For Used and Virgin Freon 113

	Test Method	Properties For Used Solvent	 Virgin Solvent
Boiling Point,F	(*)	104+	117.6
Residue	(*)	20% (max)	< 2 ppm
Water Content, ppm	Karl Fisher	1-5%	<10 ppm (Max)
Appearance	Visual	Brown/Black	Clear/White
Specific Gravity @ 25 C	ASTMD2111	1.2-1.565	1.565
Acid Number, mg KOH	(*)	<0.5	0.003 (Max)
Particulate Matter 25-100/100 ml	(*)	100+	100 (Max)

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* See DuPont Technical Bulletin for details

4. Reclamation Options

4.1 Used Solvents

Both on and off site options are available for solvent reclamation. The major options are:

- Distillation on site - this is appropriate for most solvents except carbon and paint strippers provided the economics can be justified.
- Off site toll recycling - outside contractors will reclaim and return solvents to the user for a service (toll) charge). This is generally limited to hydrocarbon solvents and carbon removers. However, these services are not universally available.
- Off site recycling - outside contractors will buy or accept many but not all solvents for reclamation. Generally only large volume generators can be serviced.

4.2 Other Materials

Aqueous emulsions - high water content emulsions need to be treated to separate out the oils and grease. The clean water can be discharged to a sewer (where permitted) and the oil and grease disposed.

Caustics - these materials should be neutralized carefully and treated in an industrial wastewater treatment plant.

Further details and examples of hazardous waste reduction in management of used oils and solvents are given in the next section.

5. Hazardous Waste Reduction Practices and Examples

5.1 Audits

Any waste reduction program should start with an audit. This can be a do-it-yourself activity or larger facilities may wish to hire an outside consultant. A standard format is given in Table 5-1 (2). As can to been from the complexity of the audit form the information needed to do a thorough job can be extensive. However, in many cases it is quite simple, but it is essential to know what is being used, how it is used and how are the waste managed.

The benefits of an audit are as follows:

- It requires thought and consideration of current practices
- Materials are identified by chemical types and properties
- Evaluation should reveal opportunities for improvement
- Regulatory deficiencies should be identified
- Corrective actions can be initiated

Table 5-1
Standard Waste Audit Format - Automotive Repairs (2)

- Name and location of shop or business
- Name of Audit Personnel
- Date of Audit
- Type of Shop
    - Automotive repair
    - New car dealer
    - Diesel repair
    - Transmission repair
    - Brake/Muffler shop
    - Radiator service
    - Alignment
    - Suspension/chassis
    - Scheduled maintenance
    - Quick lube changes
    - Body/Painting
- Size of shop
    - Vehicles serviced per week
    - Number of service bays available
- Services Provided
- Number of Employees
- Raw Materials Used

Item	Raw Material	Descrip.	Hazard Clan	ID No.	Density lb/gal	Quantity		Storage Fac. gals.
						Used gals/mo	Disposed gals/mo	
Ex 1 etc.	Parts Cleaning Solvent	Petroleum Solvent BP 310-3470F	Combustible Liquid		7	50	50	250

- Raw Material Storage (Complete for each item)
    - Raw material (Brand name/common name)
    - Item No.
    - Volume in Inventory
    - Describe usage
    - Describe disposal practice
    - Describe storage facilities

ie. 55 gal drum
Containers (Volume)
Above or underground tank
Covered/open
Indoor/outdoor
Secured

Table 5-1 - continued

- Delivery system
  - ie. Gravity
  - Funnel
  - Pump

- Material Control Practices
  - ie. Stockroom attendant
  - Access (Limited/Unlimited)
  - Signout sheet

- o Material Usage (Describe for each type)
  - Sink (Size/description/location)
  - Dip Tank (size/description/location)
  - Jet spray (size/description/location)
  - Spray hood (size/description/location)

- o Waste Material Management
  - Segregation practiced (Describe, if yes)
  - If no segregation describe practice
  - What options are available for segregation
  - Storage facilities (describe)
  - Disposal practices
    - ie. On-site recycling
    - Serviced by Equipment Leasee/Maintenance Contractor
    - Picked up by contractor
    - Disposed in Municipal Solid Waste
    - Disposed to Municipal Sewer
  - Disposal Costs
    - Oils
    - Solvents
    - Residues/Sludges
    - Antifreeze
    - Aqueous materials
    - Others

- o Material Losses
- o Provide a Schematic for Waste Management Practices
- o Prioritized Sites of Significant Waste Generation
- o Waste Management Options
- o Source Reduction Options

  - Material substitutions
  - Process changes
  - Housekeeping

- o Regulatory Compliance Evaluation and Needs
- o Recommendations for Improved Management

Table 5-1 - continued

  - Delivery system
    - ie. Gravity
    - Funnel
    - Pump

  - Material Control Practices
    - ie. Stockroom attendant
    - Access (Limited/Unlimited)
    - Signout sheet

- Material Usage (Describe for each type)
  - Sink (Size/description/location)
  - Dip Tank (size/description/location)
  - Jet spray (size/description/location)
  - Spray hood (size/description/location)

- Waste Material Management
  - Segregation practiced (Describe, if yes)
  - If no segregation describe practice
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  - Disposal practices
    - ie. On-site recycling
    - Serviced by Equipment Leasee/Maintenance Contractor
    - Picked up by contractor
    - Disposed in Municipal Solid Waste
    - Disposed to Municipal Sewer
  - Disposal Costs
    - Oils
    - Solvents
    - Residues/Sludges
    - Antifreeze
    - Aqueous materials
    - Others

- Material Losses
- Provide a Schematic for Waste Management Practices
- Prioritized Sites of Significant Waste Generation
- Waste Management Options
- Source Reduction Options

  - Material substitutions
  - Process changes
  - Housekeeping

- Regulatory Compliance Evaluation and Needs
- Recommendations for Improved Management

5.2 Identifications of Options

Once the audit has been completed, it is necessary to consider what options for waste management are appropriate. The major areas for consideration are noted below.

5.2.1 Material Selection

Can other material be found that will reduce the volume and management problems?

Example - For the Navy, a Flash Point minimum of 140 F is essential for reclamation as a fuel. By changing from low to high flash cleaning solvent, the used solvent could be blended with used oils and burned in their powerhouse. Recycling this solvent was not practical because of the low volumes and no off-site services were available.

Example - A large repair shop switched from TCA to High Flash Petroleum solvent because of a concern about the toxicity of TCA. Those operations involving mechanical equipment favored the change because of the oily film left on cleaned parts. By contrast, those involving electrical equipment did not like the change because of the oily residue.

Example - A shop using TCE was convinced by a supplier to change to a reportedly safer hydrocarbon solvent. The material provided was an odorless paint thinner which did not have the desired solvent power.

Example - Users of hydrocarbon cleaning solvents are convinced to switch to detergent formulations for cleaning all types of mechanical and electrical parts. While the cleaners may perform satisfactorily, the used aqueous mixture may or may not be legally disposed to the sewer.

Example - Hydrocarbon cleaning solvent is used to clean high precision bearings. There used product can then be distributed to less critical parts cleaning operations.

5.2.2 Segregation

Segregation is probably the single most important and readily manageable practice which can have a major impact on hazardous waste reduction. Past practices generally have not mandated segregation so all of us dump into the nearest waste container and let the disposer handle the wastes. Segregation is essential to not only proper but any kind of management of all types of wastes.

Segregation into various types of used solvents is a must to reduce both costs and problems. Grouping by the following types of materials can be useful.

- o Individual Solvents

Each solvent should be kept separate to optimize the potential for recycling whenever possible. In cases where disposal options and costs are not affected by composition, segregation may not be appropriate.

- Low Flash Materials and Mixtures with Halogenated Solvents

Materials with a Flash Point below 100°F and mixtures with halogenated solvents, especially low volumes are difficult to recycle and dispose. Generally the generator will have to either avoid these materials or pay the costs for disposal.

Example - Many shops dispose of solvents in a common receptacle. This practice generally increases disposal costs. Segregation is mandated in many areas, but is dependent upon local options.

5.2.3 Recycling

5.2.3.1 Solvents

Options were noted in Section 4.1 for recycling solvents and include on and off site recycling. On-site options require purchase of simple equipment to recycle segregated solvents. Off-site options include toll recyclers and reprocessors.

- On-site Recycling

Numerous suppliers provide equipment for recycling of almost all solvents. The equipment does not provide fractionation or separation of solvents. Equipment sizes range from 5 - 500 gals/day and costs range from $2 - 3,000 on up. There are two major types of equipment.

- Externally heated vessels with or without vacuum attachments for high boiling solvents
- Steam injection units where live stream is injected into the solvent and both are distilled and condensed. This is appropriate only for water immiscible solvents.

Examples

- A road asphalt supplier used a 5 gal/day still to recycle chlorinated solvents from laboratory testing operations. This is done to minimize disposal problems.
- Many firms have in-house solvent stills to recycle solvents such as:
    - Shipyards - hydrocarbons, Freons, paints
    - Machine shops - hydrocarbons, TCA
    - Electrical motor rebuilders - TCA
    - Ink manufacturers - organic chemicals, etc.
- Hydraulic shops use a stream injection unit to remove TCA from hydraulic oils. The TCA and oils are recycled.

- Off-site Recycling

Many solvent recyclers are available to handle relatively large generators of solvents. The National Association of Solvent Recyclers lists 15-20 major companies in the eastern US. These firms service a radius of up to about 500 miles.

Toll recyclers provide service to both small and large industries. One example is Safety-Kleen, others also provide this type service. Toll recyclers rent the equipment and solvent, when it is dirty the solvent is replaced and the unit serviced (filter cleaned or replaced). They charge for this service, but it relieves industries from handling wastes. A major problem of toll recyclers is that their services are generally limited to petroleum hydrocarbon cleaning solvents and carburator cleaners. Paint and halogenated solvents are not generally accepted. However, this may change as the industry sees the need.

6. Conclusions

Management of used solvents is becoming more of a necessity and burden to all. However, it is necessary to protect our environment especially our water resources. Indescriminant disposal of wastes can no longer be tolerated. All solvents encountered in visits to hundreds of shops in this country and overseas have been found to be recyclable. The economics and best management practices need to be evaluated generally on a site-by-site basis in order to select the optimum system. In many locations solvent recycling equipment can be paid off in 2-10 years depending upon the volumes and costs of the solvents.

References

1. Steward, F.A., & McCay, W.J., "Waste Minimization Alternate Recovery Technologies" Metal Finishing Guidebook & Directory 1986 Edition

A Hazardous Waste Reduction Audit of Pioneer Metal Finishing, Inc.

Presented by
Harry DeSoi
Pioneer Metal Finishing, Inc.
Franklin, New Jersey

Hazardous Waste Reduction Audit
of
Pioneer Metal Finishing Inc.

Identify Problems

As with solving any problem the problem must be clearly identified and the final goal must be clearly defined. Pioneer Metal Finishing Inc. provides a service to manufactures. This service is to electroplate copper, nickel and chrome onto substrate metals consisting of steel, cast steel, zinc diecasting and brass. The buffing room had potential air problems but they will not be discussed at this time.

The problems were identified and divided into the following areas:

#1 Dragout from Hex-Chrome tanks
#2 Dragout from Cyanide-Copper tanks
#3 Dragout from Nickel tanks
#4 Dragout from Cleaner ranks
#5 Dragout from Acid tanks

The most serious problems were yet to be identified.

#6 Periodic dump of Diecast soak
#7 Periodic cump of Oil containing Steel soak
#8 Periodic dump of Diecast electro-cleaner containing large quantities of Zn and Cu and Cr.
#9 Periodic dump of steel electro-cleaner containing Cr metal and very high content of caustic.
#10 Periodic dump of 2% sulfuric with up to 2000 ppm zinc
#11 Periodic dump of 75% hydrochloric with up to 1000 ppm copper plus up to 600 lb of ferric-chloride
#12 Periodic dump of saturated rack strip with very high content of copper, nickel and chrome
#13 Periodic dump of saturated strip used to strip rejects. This contains high volumes of copper and nickel.
#14 Water from vibratory finishing containing large volume of zinc metal, media (ceramic and plastic) and vibratory compounds that do not want to let go of the metal.

Upon close examination we discovered that we had problems within problems that were not to be solved by simple treatment steps. Most treatment "experts" selling treatment systems had very little experience in solving problems when small quantities of metals were left in the water that had to be discharged. They were good at getting 300 and 400 ppm of metal out but were confused when you get down to 6 to 10 ppm and the remaining metal will not drop out. Some of these chemical companies have admited that their proprietory chemicals will not release all of the metal by using conventional treatment methods. Some act as if it is not a problem while others are concerned.

Through trial and error we found these additional problems:

#15 One soak tank contained a chemical that at a pH of 9.5 to 10 retained metals.
#16 One elecrocleaner was heavy formulate with chemicals used very widely in the cleaning industry which are very difficult to treat.
#17 One plating bath contained enough ammonia to retain enough metals to place our discharge violation even after treatment.
#18 Concentrated strip would not treat by conventional methods

The most serious compliance problem of all came last. If we could install a system that would produce acceptable water on a reliable basis what would me do to stay in compliance as equipment ages and normal unexpected problems present themselves? On a normal day there are many variables in the plating that create some rejects. In waste treatment there could be many variables that could produce water in violation of State and Federal laws.

Reducing Expenses

Now that we found most of our problems we had to look at the expense of correcting these problems. The cost of equipment is significant but the week to week expenses can even be more detrimental. We had to look at the most expensive treatment problems and see if we could change some of the products we were using.

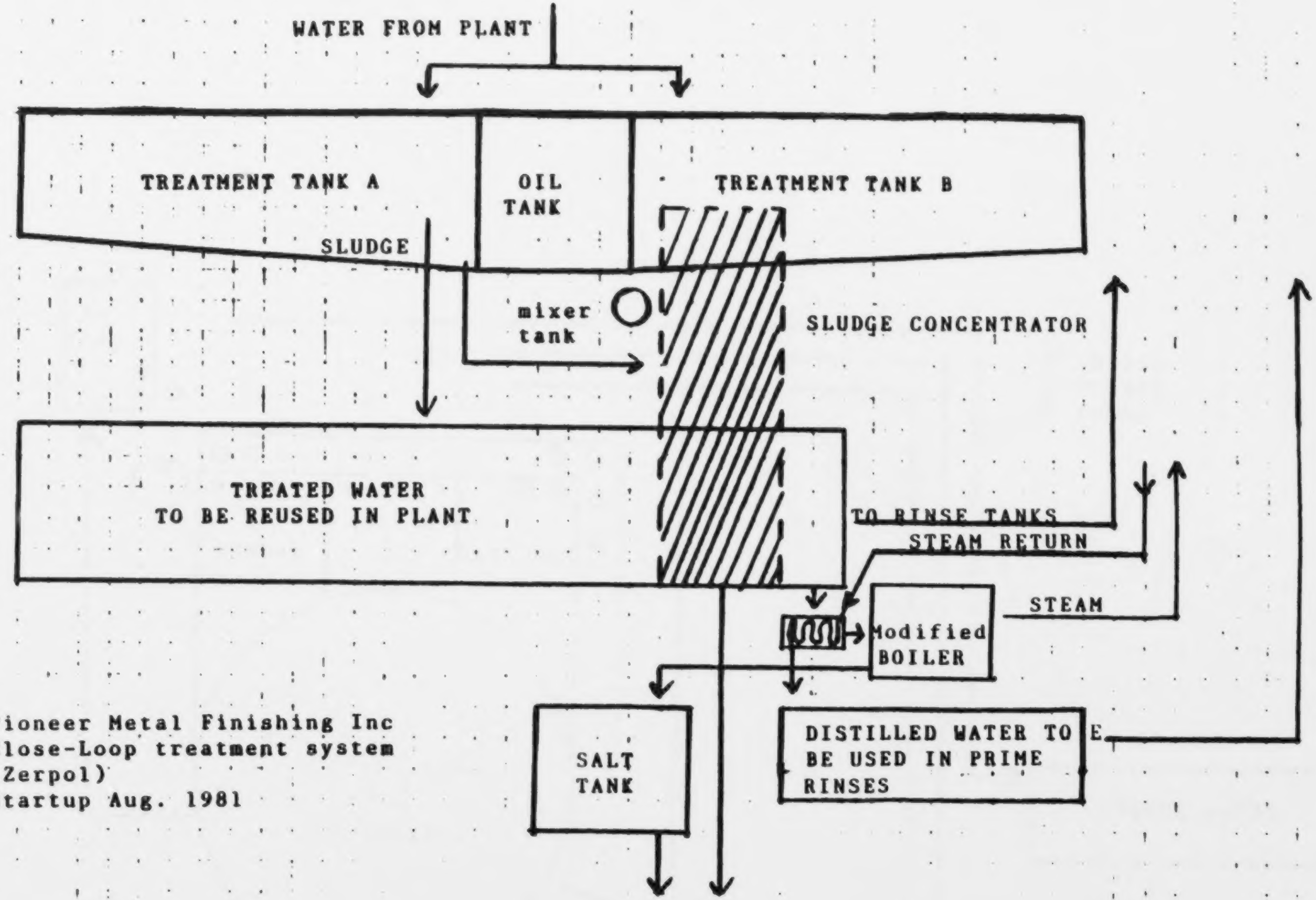
#1 We changed one of our soak solutions to one that is more treatable.
#2 We changed products in one of our electrocleaners to a product that treats quite easily.
#3 We changed from hexovalent chrome to tri-valent chrome in our chrome plating line. We then went to a tri-valent chrome containing no ammonia. Trivalent chrome is treated by simply raising the pH to 9.5. Hexovalent chrome solutions are 20 times more concentrated with metal and very costly to treat.
#4 We installed spray rinsing, educated employees, redesigned plating racks and increased drip time to conserve on chemicals drug out of plating baths.
#5 Replaced batch dump strips with electro strips that can be filtered. Batch strips are very expensive to treat. Most must be greatly diluted to be treated properly if they are cyanide strips.
#6 The greatest area to reduce expenses was in the type of treatment. From 1975 to 1981 we used a segregated-continuous discharge system. From 1981 to present (1987) we have used a close looped batch treatment system.

Continuous discharge system was heavy on chemical use, heavy on maintainance, heavy on sludge production and heavy on labor. Approximate expenses were 10% of gross sales. Batch treatment-Close Loop system has low chemical use, low on maintainance, low in sludge production and very low on labor. Approximate expenses are 3% of gross sales.

Reduce Liability

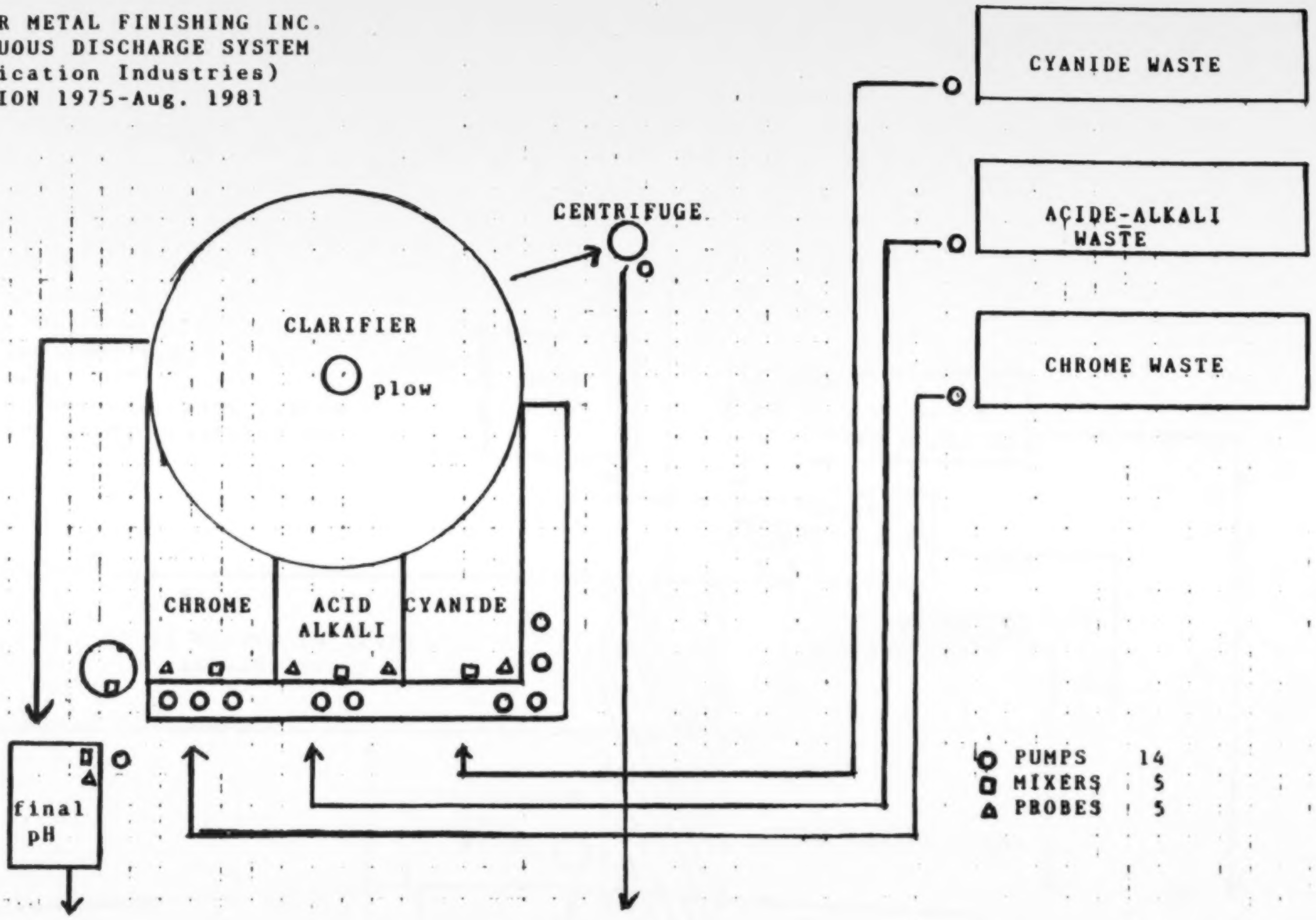
The most threatening liability is the potential of discharging in violation of Federal, State or local laws. The way we reduced this liability to the lowest possibility was to replace our continuous discharge system with a close-loop system that captures all rinses water and dumps, treats water, desalts the water through modified boilers and reuses the water. While there was water leaving the plant the liability factor was greatly increased. With no process water leaving the plant the liability factor is greatly reduced.

Other steps to reduce liability is to reuse as much as possible in the plant, substitute less toxic chemicals for more toxic ones and throughly investigate the companies to be used to haul any waste from the plant.



Pioneer Metal Finishing Inc
Close-Loop treatment system
(Zerpol)
Startup Aug. 1981

PIONEER METAL FINISHING INC.
CONTINUOUS DISCHARGE SYSTEM
(Purification Industries)
OPERATION 1975-Aug. 1981



A Waste Audit/Reduction Program for the Printing Industry

Presented by
Richard A. Goldbach
Environmental Coordinator
United States Printing Ink Corporation
East Rutherford, New Jersey

Waste Audit/Reduction Program

UNITED STATES PRINTING INK CORPORATION

The increasing liabilities and public concern with the environmental exposure to hazardous chemicals and substances have increased the concerns of the Corporate Headquarters. Besides the EPA regulations dealing with RCRA and hazardous waste, many states have adopted more stringent regulations which increase the scope of what is considered a hazardous waste or nonhazardous waste. It doesn't really matter if the material is a nonhazardous waste if you are to dispose of this material in a secure landfill. In five, ten, twenty years from now it might be considered a hazardous substance, therefore, we would be liable for any Superfund cleanup at a site even though the material itself might not be a hazardous material. This is due to the EPA regulations changing and redefining the characteristics of a hazardous substance.

We have to look at the many characteristics of waste and determine the alternative for disposal of the material which may include waste reduction, landfilling, incineration, or recycling. All of these things must be taken into consideration when we are thinking about Corporate Capital Expenditures for the year. Many incentives for the reduction of waste generation are being considered by the Corporate office. It is desirable as far as environmental, it can reduce our potential liability for problems associated with the offsite waste handling and disposal. We must evaluate our waste streams to determine if waste minimization, source reduction, recycling, waste treatment or incineration would be the best alternative for our waste generation. The best alternative at the present time would be incineration since total destruction of the waste would prevent further liabilities from superfund sites. To accomplish such a program would require the committment of top management, allocation of funds and basically the support of the technical staff to investigate alternative methods of waste reduction and routes of disposal. Although the initial objectives may not return a net profit for the company, in the future it may prevent or lessen the liabilities and clean-up cost.

To establish an Environmental Audit/Reduction Program, we must plan and have scopes of investigation in mind. Waste is not the only by-product of concern, we have other items which might also be included, such as, waste water discharge, air pollution control, and empty drum disposal. In order to determine what approach we are going to take in this program we have to first determine what are our waste streams, how are they generated, and what are the waste characteristics. Are these waste streams hazardous or nonhazardous according to State and/or Federal regulations? This does not make any difference in today's rules and regulations because what eventually might happen is that the material which is not a hazardous waste today could be a hazardous waste tomorrow. We have to review our processes and formulations to determine if any of the materials can be replaced or eliminated to deter the type of waste generated and reduce the volume. Research and development will have to play an important roll in the reformulation and reduction program.

To begin our Waste Audit/Reduction Program we have to first have a pre-audit schedule of each of the individual plants, meaning we need to prepare a list and inspection agenda, compile data and select target waste streams, inspect the plants, generate a comprehensive list of minimization objectives, evaluate the options and select the options for further analyses. We would have to conduct technical and economical feasibility studies, suggest preferred options, design and construct major monitoring performance programs. Determination of the waste streams would include:

A. What are the waste streams generated?
B. How can we reduce them?
C. Is there a way of eliminating them?
D. How do we determine if the material is actually a hazardous waste?

Once we have determined the above, we have to look at the options that are available in today's technology. We could consider the possibility of purchasing a higher grade of raw material, tighten our equipment inspections, improve our operators training and provide closer supervision of our personnel.

One of our main objectives here is to reduce our waste volume and that may be accomplished by segregating the different waste streams and using recycling drums, buying raw material in bulk, purchasing the material in pre-weighed packages, and investigating the improvement of mechnical operation of equipment through engineering. We would have to ask ourselves:

A. Is this the best way of handling this material?
B. Is it the best to optimize the waste generation?
C. Is there a better way that we can develope and incorporate into our production?

It isn't waste generation alone that is important, we have to take into consideration also the waste that is generated through clean-up of plant equipment, floor cleaning and general housekeeping of the plant. In fact, sometimes the cleaning materials that are utilized to clean the equipment and plant are worse than the actual waste streams generated from production. Of course any waste reduction program that we would set into effect would have to be cost effective, not only for the plants but for the corporation itself. Therefore, we would have to evaluate each of our alternatives very closely, and evaluate each one individually.

Due to the fact that our waste streams are basically nonhazardous, disposal can be accomplished with minimal problems; therefore, we at United States Printing Ink Corporation have decided that all waste should be incinerated. The ink oils used in production are pure and have a high BTU value making our waste ink streams very economical for incineration. The waste can be used as a supplementary fuel to heat cement kilns and other type of incerators which require a high BTU value waste stream. By incineration of our waste it would eliminate many of the possible liabilities that would be involved in land disposal. At the present time we are investigating a situation which would incorporate all of our plants throughout the twelve states in which our manufacturing plants are located, to have our waste incinerated at specific cement kilns. The largest problem we are currently faced with is the high viscosity of our waste inks. For them to be incinerated the viscosity would have to be greatly reduced. The waste ink viscocity would have to be below 200 cps in order for the material to be atomized economically in the kiln.

Understanding the Resource Conservation and Recovery Act (RCRA) rules and regulations can cause confusion in the determination of what actually constitutes a hazardous waste. As ink manufacturer we work with and assist our customers to develope an understanding of the RCRA rules and regulations in order for the disposal of their generated waste. We suggest to our customers that they should segregate their waste streams, solid from liquid, in order to prevent any possibility of cross contamination from pressroom materials which might alter the waste characteristics. Waste ink according to RCRA is a nonhazardous waste, it is noncorrosive, nonreactive, nonignitable, and non-EP Toxic based upon numerous tests performed by outside certified laboratories. We strongly urge all of our customers to segregate their pressroom material and dispose of it legally and properly. You must have an EPA ID number for manifesting of the waste even if the material is not a hazardous waste; when it comes down to it if you don't know where your waste went you will still be liable for it. You must keep in mind that the generator of a waste stream is liable no matter to whom you release your waste to. It is your responsibility to know where it is going, what will happen to it, and how the facility will secure it from contaminating the environment. If your waste should end up in a river or along a roadside you can be held responsible for any cleanup cost and contamination, you could even be faced with the possibility of a willfuf violation of the RCRA regulations.

Investigation of the waste disposal facility is very important. Even though the state may say at this time that everything seems to be in order and that there are not any violations against the disposal facility, you don't know what is going to happen tomorrow. Very close tabs have to be taken with the selection of a disposal facility. Investigate them, look at them, visit them if possible and determine how they are handling the waste. Are there alot of spills on the ground? How is their housekeeping? Where are they disposing of their empty containers? Do they have the proper EPA ID numbers and are they allowed to accept this type of waste stream? Do they carry enough liability insurance to cover any superfund clean-up due to contamination? Liability extends beyond your waste stream, beyond anything you can think of. If you produce any type of waste, hazardous or nonhazardous, you are still responsible for it and therefore you should know what's happening to it. No matter what type of waste is generated, remember, handle all waste in an environmentally sound manner. Destroy or recycle waste rather than contain or bury them. Whenever feasible you should work the waste ink back into the ink system, of course this can only be done with the segregation of your waste.

If you are not registered with the EPA as a generator or small quantity generator, you should obtain an EPA number. By doing this it would allow you to dispose of your waste with legally documented manifest. Even though you might be considered a small quantity generator, that is a person that generates between 100 kilo's to 1000 kilo's or 220 pounds to 2,200 pounds a month, you are still regulated under RCRA and you have to keep certain records and manifest available for state and/or federal inspections.

If you need assistance with the small quantity generator rules and regulations, you have many organizations available to you that are quite versed in the situation (ANPA, GATF, PIA). They have programs established that can help you with waste disposal information, possible collection points within your local, and suggestions for the reduction of your waste volume. Liability insurance is very expensive now a days and it's only going to increase, therefore, we must learn to reduce our waste volume. Capital expenditures may be high but down the line it will save you and your company many problems including financial and possibly criminal charges if it is a willful violation of the RCRA Act. Through a waste audit/ reduction program, you could evaluate and determine what are your best alternatives, and what is the most reasonable method for financial outlay.

Submitted by
Richard A. Goldbach
Environmental Coordinator
United States Printing Ink Corporation

Hybrid Membrane Systems in Waste Management

Presented by
William F. Weber
Du Pont Separation System
E. I. Du Pont De Nemours & Co. (Inc.)
Wilmington, Delaware

(Originally Presented at the Membrane Technology Planning Conference
Cambridge, Massachusetts - November 6, 1986)

INTRODUCTION

Whenever one is pursuing a new market, there are several basic questions which need to be answered.

The crossflow membrane filtration market is no different.

MARKET POTENTIAL

The first question one hears is: "How big is the market?"

Last year, we outlined Du Pont's perspective to this question. As you'll recall, the forecast for sales of membrane systems and services in gas and liquid processing applications was expected to increase from $500MM in 1985 to over $2MMM by 1995.

Our experience since that time has confirmed that there are significant and emerging opportunities for membranes in food processing, aqueous waste management, gas separations and biotechnical applications. Specifically in the market of treatment of hazardous wastes, the potential for the use of membrane systems is outstanding. As can be seen in Figure 1, approximately 270 million tons of hazardous wastes regulated under the Resource Conservation and Recovery Act (RCRA) are generated in the United States annually. Over 60 percent of this total is in the form of dilute aqueous wastes, most of which contains 0.1-1.0 percent of hazardous constituents. Industry spends about 11 to 12 billion dollars a year to treat these wastes. Historically, most of this treatment has consisted of on-site conventional primary and/or secondary treatment prior to discharge to a local surface water or municipal sewer. However, the regulations on these discharges is being tightened every year, mandating the need for additional treatment. The technologies being looked upon as most likely to fill this treatment gap are carbon absorption, ion exchange, steam/air stripping and membrane separation. If membranes can be adopted to even a small portion of this opportunity, it will represent a very attractive market niche to go after. We estimate membrane systems and services sold into this emerging market niche within the last year was over $25 million dollars.

CRITICAL SUCCESS FACTORS

Once one has sufficiently proven that the opportunity is a large enough carrot to go after, the next question is "What do we have to do to get it?".

First, one has to be sure to target the right applications, especially because in most waste treatment cases membranes are only one of several alternate separation technologies available. Therefore, to determine whether or not membranes are right for a given application, one must consider the specific site conditions such as:

- System Size - flow rates up to 100,000 gallons per day (gpd) are often attractive.
- Nature of Constituents to be Removed - the higher the molecular weight, the better.
- Purity Requirements - removal of over 95 percent often needs polishing steps in addition to membrane separations.

But even if a potential application fits these criteria, there are several other even more important critical success factors required from the supplier of the membrane system, as follows:

- Understanding of the membrane capabilities and limitations.
- Access to various kinds of membranes - including microfiltration, ultrafiltration and reverse osmosis - as well as various configurations - such as spiral, hollow fiber, tubular and plate and frame.
- Ability to provide non-membrane options for pretreatment, polishing and/or ultimate disposal.
- Ability to engineer the integration of membrane unit processes with other unit processes into a hybrid system.
- Ability to deliver a low cost system.
- Ability to provide full service for these systems, including start-up, operation and troubleshooting.

It is worth repeating that the capability to integrate membranes into an overall hybrid separation system is critical to be successful in emerging separation applications.

CASE HISTORIES

Finally, once one has reasoned that a target market is big enough at which to shoot, and one has determined a direction in which to shoot, only one question remains - "Can you prove it?".

The remainder of this paper will give a brief review of some of the applications in which we have recently been involved which begin to "prove out" that membrane systems do work!

1.) TEXTILE FINISH WASTE

The first case deals with the use of a membrane system to concentrate industrial wastes for more economical disposal. It involves textile finish wastes from the manufacture of synthetic textile fibers.

Textile finish wastes are similar in some respects to metal finishing oils, but they can be more difficult to treat because each textile product may use a different finish formulation and each plant uses a variety of finishes simultaneously. A typical formulation may contain 8 to 10 components, many of which are proprietary. In general though, the finish is a mixture of surfactants, oils and polymers.

At this site, the waste disposal problem was two-fold. First, the permit for the existing disposal technique of spray irrigation onto a field was about to expire and the manufacturer did not expect it to be renewed. Secondly, the manufacturer was introducing several new finish formulations into the process which would introduce a solution waste in addition to the previous emulsion waste.

The first proposed remediation scheme can be seen in Figure 2. It consisted of a dual collection system to segregate the emulsion and solution waste and an alum treatment system to chemically split the emulsion into oil and water phases. The remaining water from the emulsion would be treated on site by biotreatment and the emulsion sludge and solution waste were to be shipped off site for disposal.

As an alternate, we proposed to install a membrane system to treat the the combined finish oil wastes from the entire plant, thereby eliminating the need for the dual collection system and the alum treatment plant (see Figure 3). We conducted pilot tests with both simulated waste streams and actual plant samples using both spiral wound and hollow fiber membranes. We found that although both membranes suffered an almost immediate reduction in productivity, after the system had stabilized, the hollow fiber devices yielded a higher productivity. The reason for this was traced to the surface active ingredients in the finishes, which coat the membrane and reduce their permeability to water. Having a much higher water flux, the spiral wound elements suffered from this effect much more severely than the hollow fiber. As seen in Figure 4, the pilot study results for the hollow fiber membranes were very encouraging. High volume reduction of both emulsion and soluble wastes was achieved with extremely low penetration of finish through the membrane.

Based on the pilot test results, this alternate remediation scheme was chosen for the full scale system which is shown in Figure 5. It is a 5 gallon per minute (gpm) system which operates in a batch mode for about 3 to 6 hours per day. The waste from the various spinning machines are put into a collection tank to allow the de-emulsified oils to rise to the surface. This material is decanted into drums for incineration. The remaining liquid is pumped through a 1 micron filter and then a biocide is added. From the RO feed tank, the material is filtered again, put through a heat exchanger to maintain 86°F, and pumped at 400 psig to parallel hollow fiber permeators. The permeate goes directly to the biotreatment facilities and the concentrate is recycled back to the feed tank. In this way, the oils are concentrated to as much as 35% by weight.

After each batch treatment, a regular cleaning of the membranes is done with a detergent solution at a reduced pressure. This prevents any residual oils from de-emulsifying within the permeators. Once completed, the spent cleaning solution is added to the RO feed tank.

We found that membranes performance could be improved by the addition of certain detergent agents to the feed tank which had the effect of improving circulation in the permeators. We use what we call a "working solution" method, in which we estimate the quantity of detergent necessary to concentrate a given volume of waste and added it to the feed tank as it is filled the first time.

This system has proven to be extremely cost-effective (see Figure 6). By eliminating the alum splitting system and dual waste collection for each machine, capital costs were reduced from $900,000 to $150,000 for the membrane system. More importantly, due to the volume reduction of waste for off site disposal, disposal costs have been reduced by over $250,000 per year. Due to the success of this system, several other textile manufacturing plants have modelled waste concentration systems after this one.

2.) PETROLEUM PRODUCTION BYPRODUCTS

Another example of waste concentration involves the byproduct stream from offshore oil production. It illustrates the flexibility and varied experience that a membrane supplier who is also a large industrial company can bring to developmental technologies as well as commercial ones.

The byproduct stream consists primarily of seawater with residual amounts of organics, primarily acetate-type compounds with molecular weights ranging from 80 to 110. The organic level was about 80 percent higher than the EPA limit however, which prevented the disposal of this byproduct stream directly back into the sea.

A pilot program was developed to determine if an on-site, space-efficient, low-cost treatment system could be designed to eliminate or greatly reduce the volume of wastewater being shipped to land for disposal. The studies looked at both hollow fiber and spiral wound reverse osmosis membranes as well as spiral wound ultrafiltration membranes. The ultrafiltration membranes had insufficient rejection rates of the organics and the standard seawater RO membranes had unacceptable recovery rates, primarily due to osmotic pressure buildup.

Therefore, evaluations were also made on several reverse osmosis membranes being developed to operate at feed pressures up to 1500 psig. These membranes are tailored to provide variable passage of selected constituents.

As can be seen in Figure 7, in this case, the rejections of the acetate-type compounds was quite good while much more salt was allowed to pass through the membrane. In fact, the use of these membranes in the system reduced osmotic pressure buildup and achieved higher recovery rates/volume reductions. The system we designed was able to produce product water whose quality was well within the EPA disposal limits (80 percent organic reduction) as well as reduce the volume of the brine stream by a factor of 5 to 10 times.

3.) GROUNDWATER REMEDIATION

In this case, membranes economically assisted more conventional remediation technologies to restore groundwater which had been contaminated with industrial processing waste. At the site in question, the originally proposed remediation scheme called for a groundwater withdrawal of 130,000 gallons per day via a drain tile collection system for subsequent treatment. It was determined that this groundwater flowing into the collection system was picking up in excess of 200 pounds of wastes (primarily volatile organics) per day. The treatment objective was to remove over 98 percent of the total groundwater volatile organic compounds (VOC) and reduce each VOC constituent to no greater than 50 parts per billion (Figure 8).

Four alternative treatment systems were considered:

- biodegradation in a retention pond, which was considered too expensive;
- air stripping, which was politically unacceptable in the area since it would essentially transfer a large quantity of hazardous waste from the water into the air;
- steam stripping, which was technically feasible and more cost effective than a biopond;
- membrane system, which was considered to be potentially the most economical solution if technical viability could be demonstrated.

Accordingly, in-house feasibility tests were performed with laboratory spiked samples of the volatile organic compounds. Rejection and flux results of several different commercially available reverse osmosis membranes showed the "Permasep" B-10 permeator to be the most effective membrane. Subsequently, a 5 gpm portable pilot system was tested on site at a wide variety of operating conditions, including feed pressures from 240 to 1000 psig and recovery rates from 38 to 92 percent. Results of these tests are summarized in Figures 9 and 10.

These tests demonstrated membrane concentration was effective in reducing the VOC content by 85 to 90 percent, and improvements were identified which raised that to 90 to 95 percent. A polishing step using air stripping would have achieved the 98 percent VOC removal goal and still kept the total discharge of VOC's to the air at less than the goal of 10 pounds per day.

Based on the pilot test results, the conceptual design for a full scale system was prepared and is seen in Figure 11. When compared to the projected performance and cost of a steam stripper, the hybrid system of a membrane system/air stripper was shown to be effective alternative as can be seen in Figures 12 and 13.

4.) RESOURCE RECOVERY

Here, an in-line closed loop system is used to prevent valuable raw materials from becoming unusable and thus disposed as wastes.

In one case, for example, we developed a system using membranes to recovery copper cyanide from the rinse water in a plating operation. Details of this system are in Figure 14. The system separated the plating water into two streams: a product stream having low TDS for direct disposal to the public sewer or reuse in the rinse tanks, and a highly concentrated brine containing the plating chemicals for reuse in the plating bath. The membrane system operates at approximately 1000 psig feed pressure and is sized to treat 2.2 gpm feed flow (see Figure 15). The system operates at 90 to 95 percent recovery and rejects 97-98 percent of the copper cyanide.

This system cut the company's processing costs two ways. First, it allowed them to eliminate a waste treatment system along with the associated chemicals, manpower and water. Second, it reduced their total purchases of raw processing materials. The combined savings result in a payback of the system cost within a matter of months.

In some cases, the payback period for a resource recovery membrane system can be even shorter! We are presently doing feasibility testing in a case involving the recovery of an exotic dispersing agent used in a polymerization process. The system would be used to concentrate the effluent of an exhaust stream which has been processed through a scrubber. The full scale system would be about 20 gpm. Since the value of dispersing agent used in this process is over 5 million dollars annually, the cost of a membrane system could be made up within a matter of days!

CONCLUSIONS

Du Pont is committed to pursuing the waste management market with hybrid membrane systems!

Why, can be seen from the answers to these three questions:

- How big is it - So big, that it's scary.
- How do we get it - By providing the total solution to the separation need.
- Can you prove it - As shown in these examples, the proof is in the pudding.

These answers also explain why we've gotten continued interest from potential clients for new applications. We've been able to demonstrate the significant economic, environmental, and product quality advantages over other separation technologies. But our demonstrations have only been successful in these unique applications because we've committed ourselves to providing the total solution to a client's separations need. We have tapped into the extensive resources and experience of the Du Pont company to provide hybrid membrane systems which are integrated in the given site specific conditions of an application. For a membrane system to be successful any or all of the following must be offered: problem analysis, feasibility testing, solutions design, systems fabrication and installation, and field service. Only by assuming the full responsibility for the separations solution do we foresee the continued acceptance of membrane separation as the next viable unit process for these emerging applications.

Figure 1

Annual Estimated Hazardous
Waste Generation

Total = 270 Million Tons

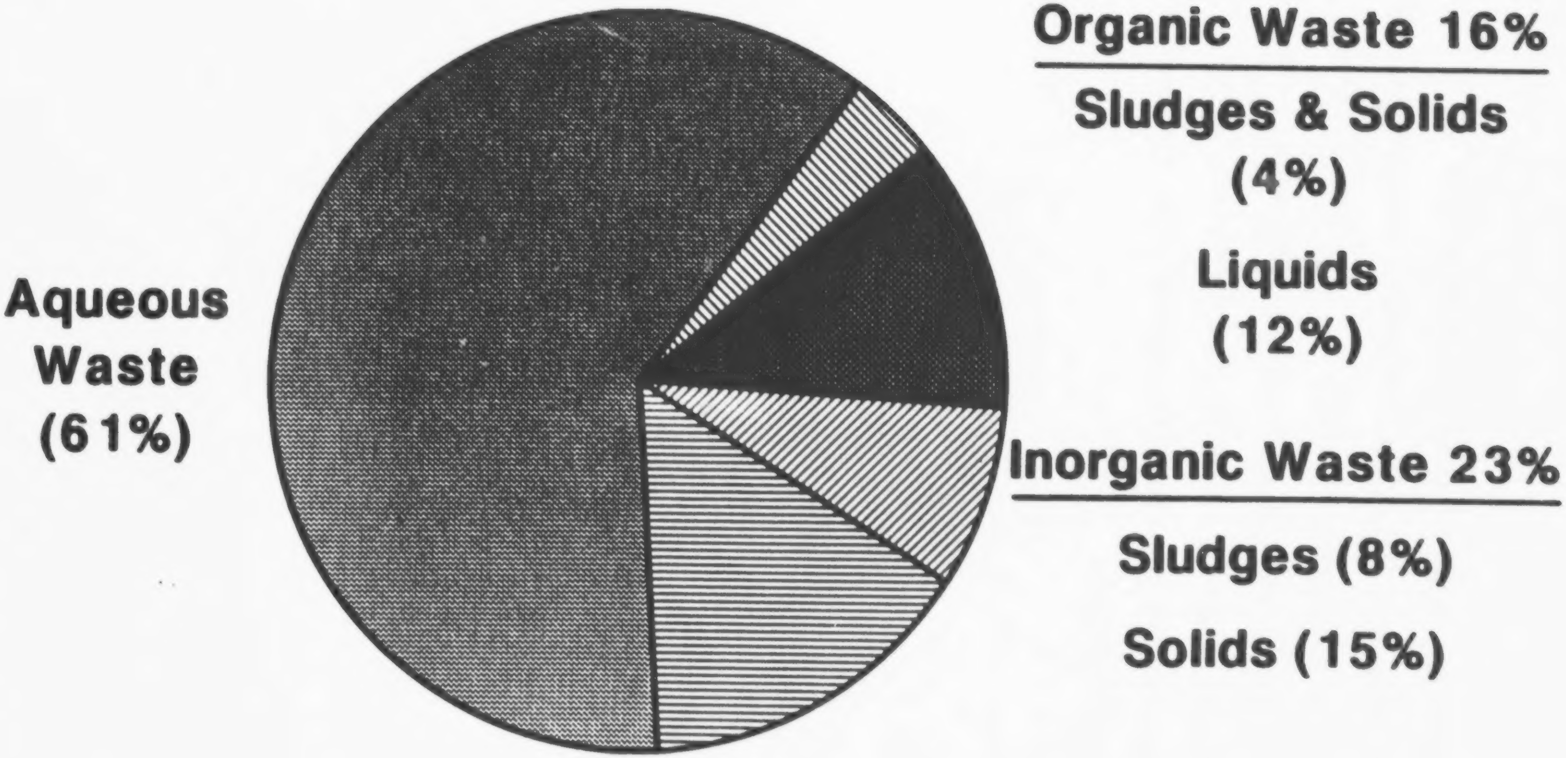


Figure 2

Waste Oil Treatment
Emulsion Plus Solution Finish

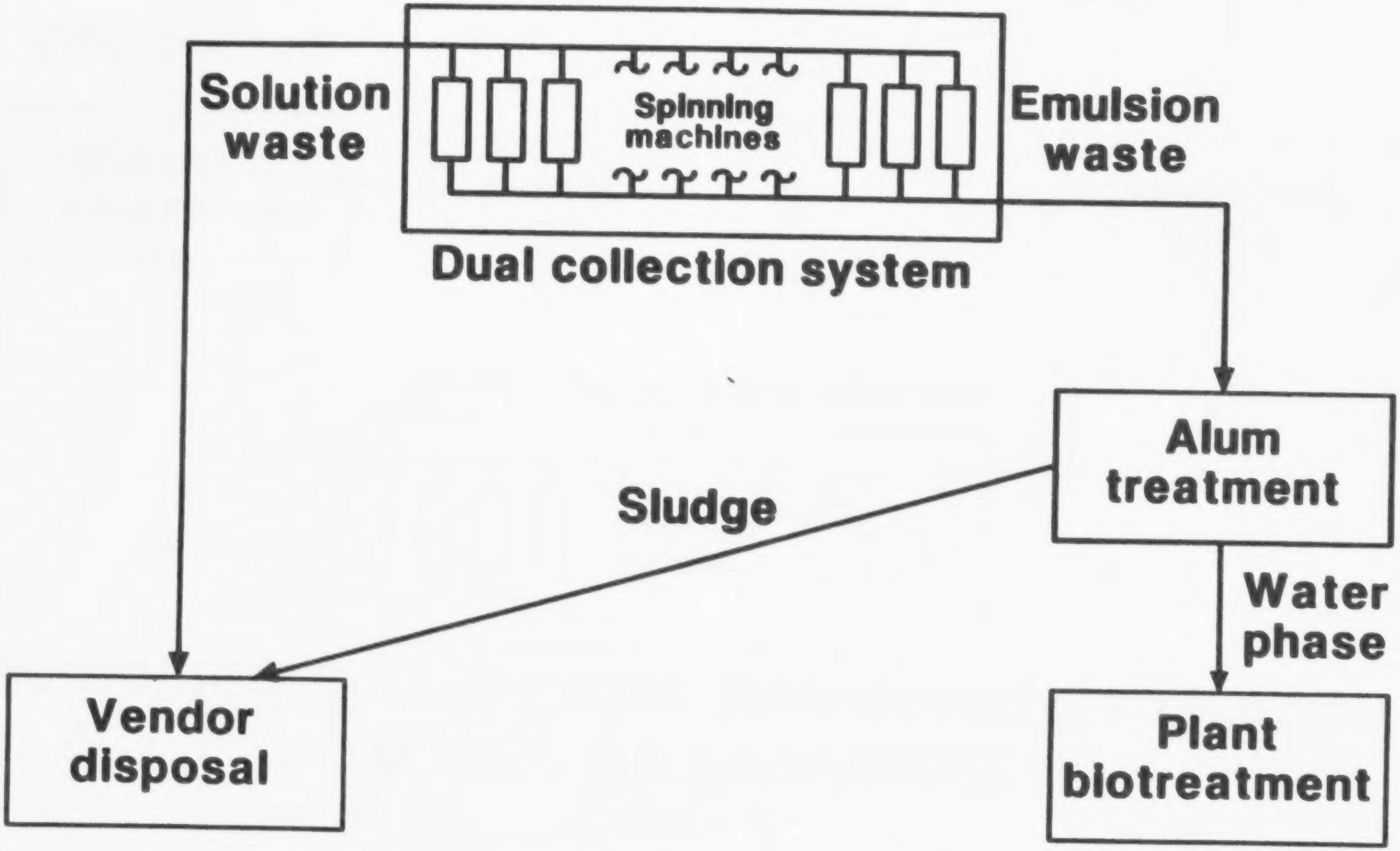


Figure 3

Waste Oil Treatment
Combined Waste Using Membrane Separation

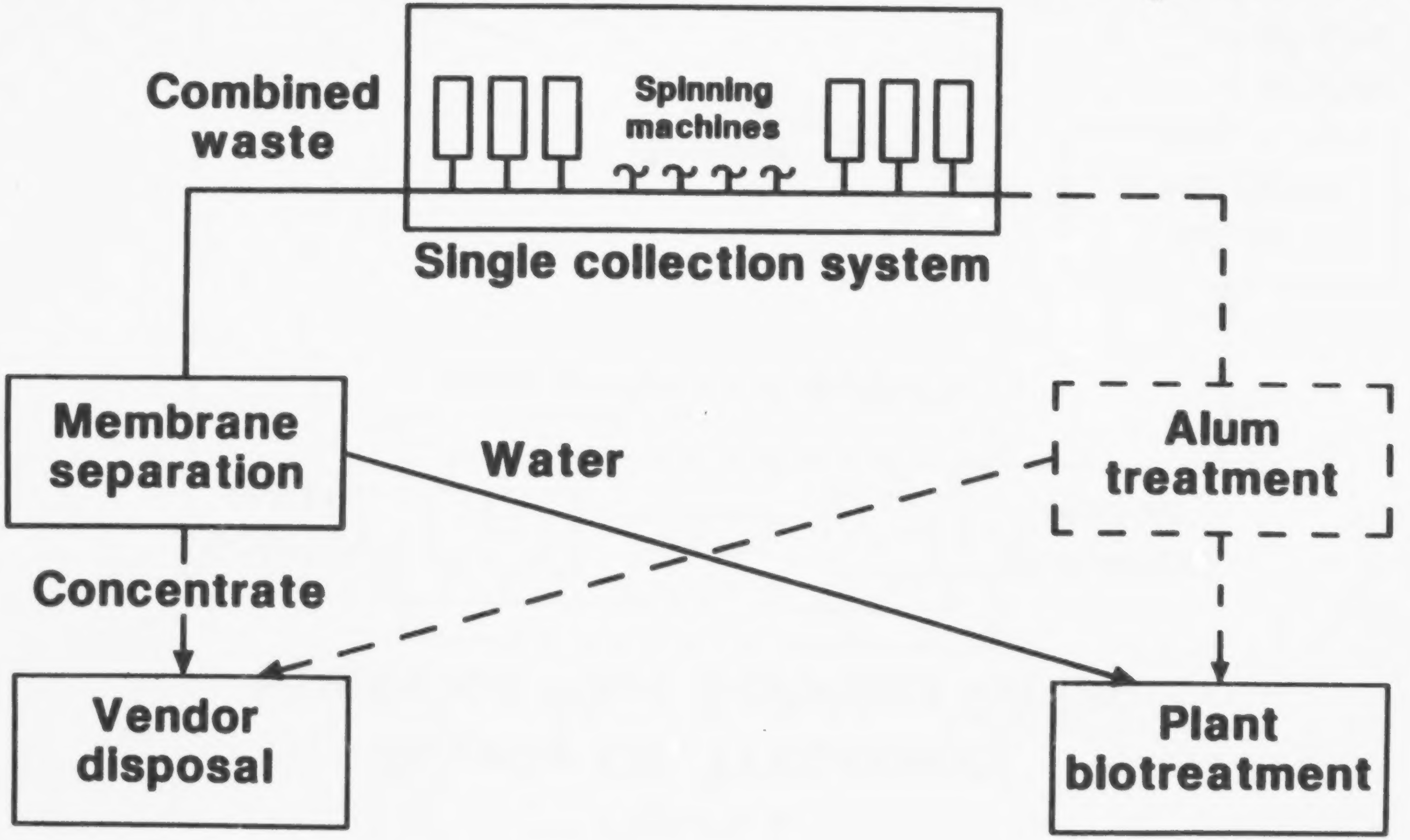


Figure 4

Permeator Productivity vs. Finish Concentration

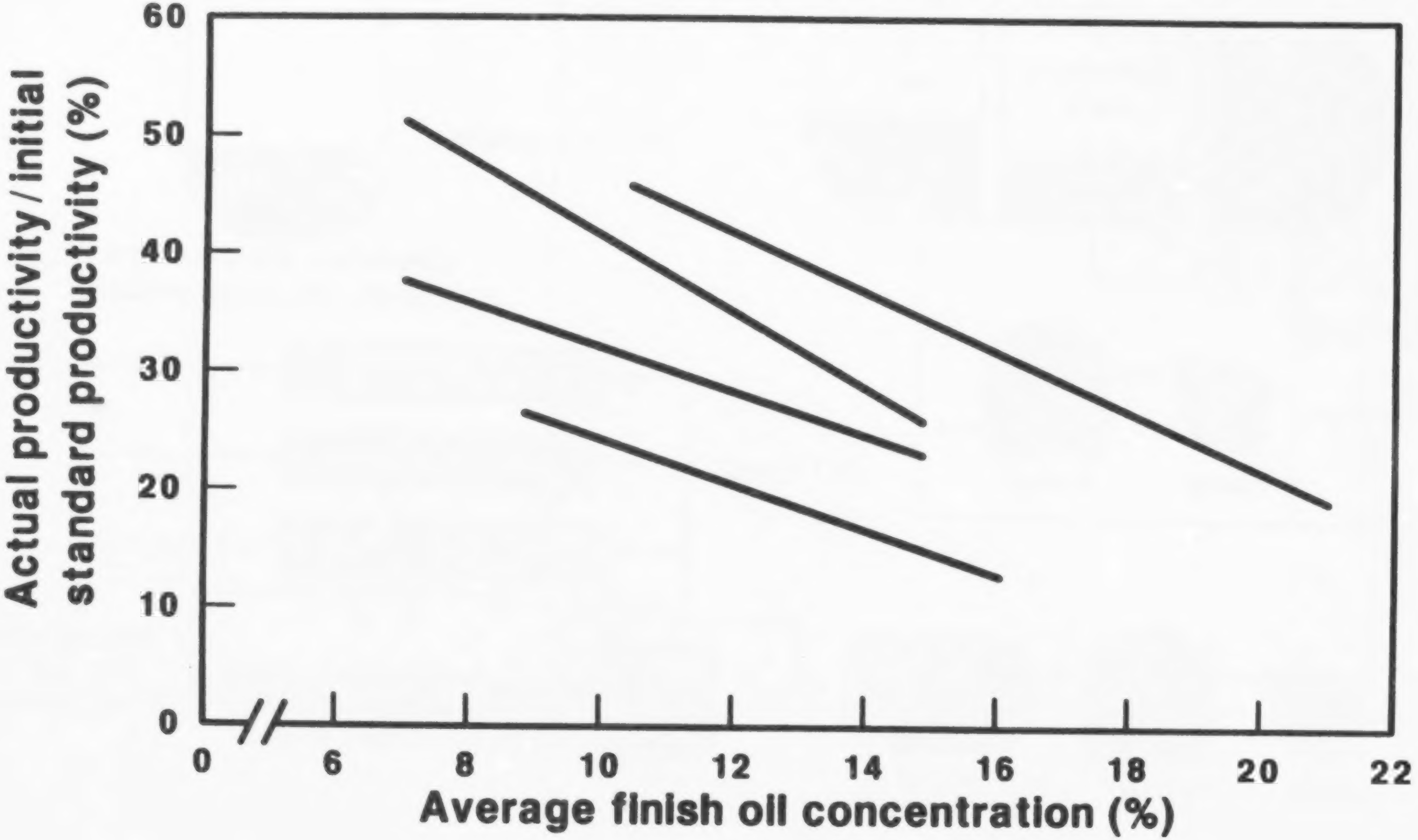


Figure 5
RO System

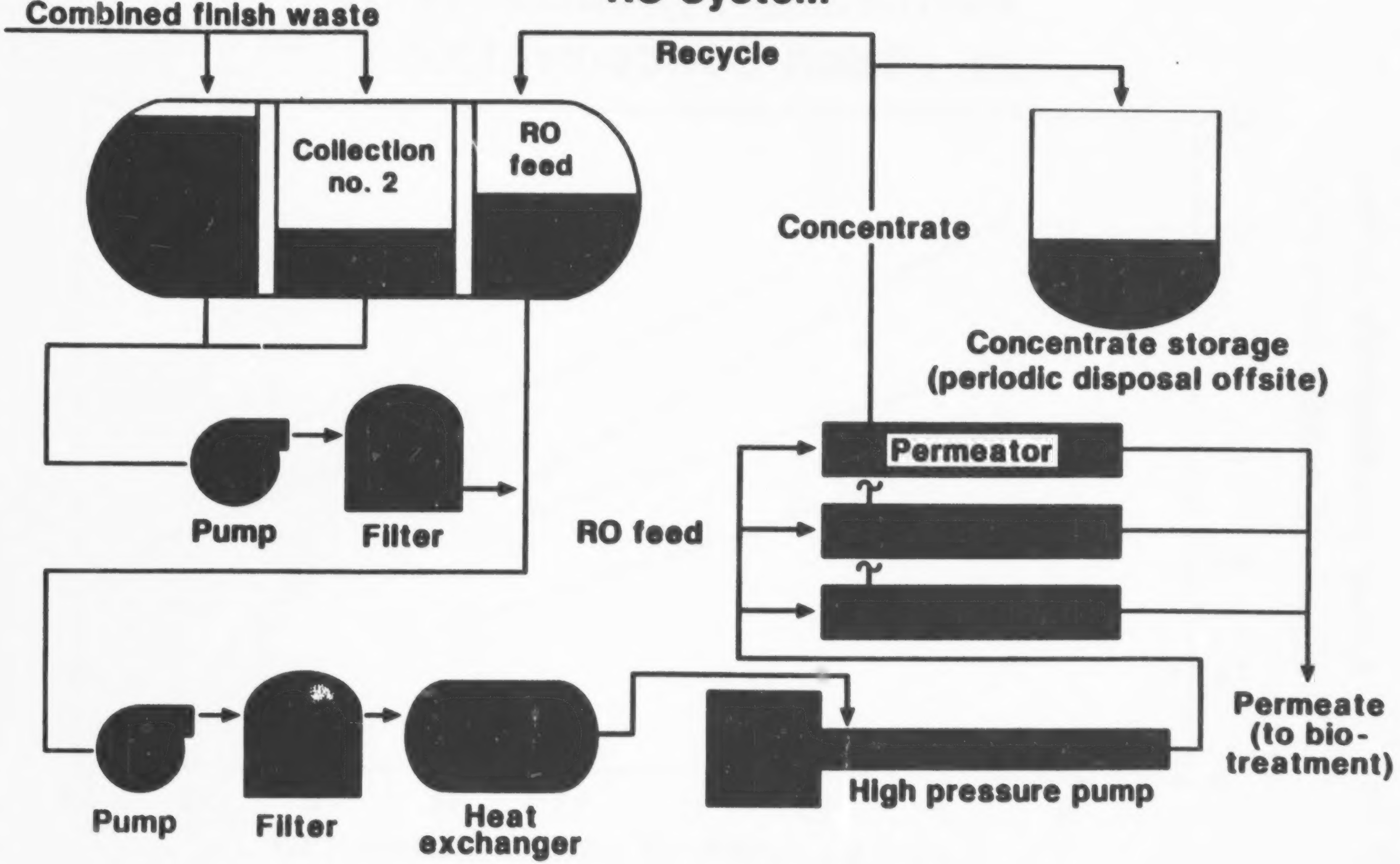


Figure 7

TDS Rejection vs. O & G Rejection

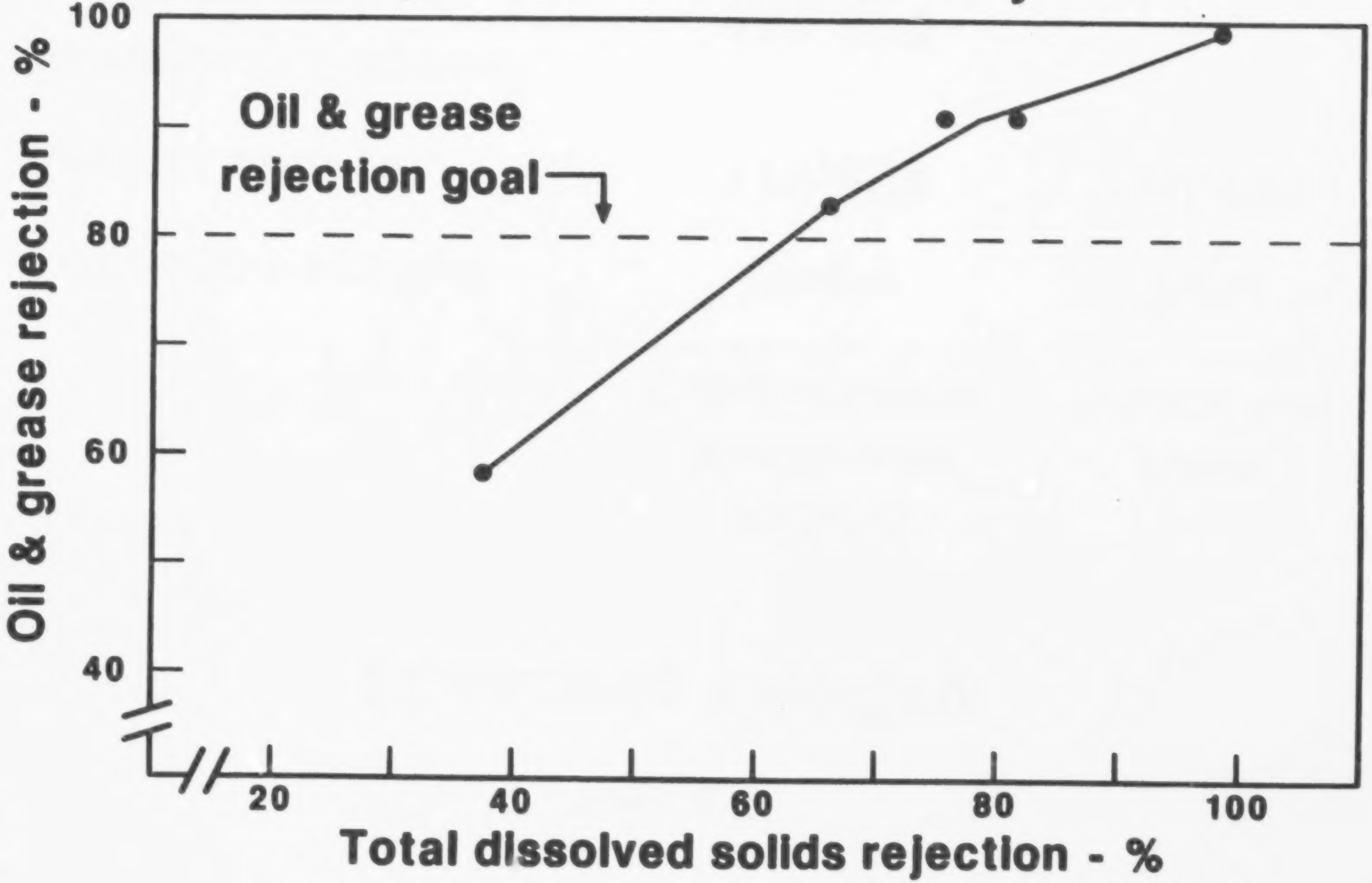


Figure 6

Economic Viability

	Hybrid Membrane Concentrator	Alum Treatment
Collection system	Single	Dual
Capital cost ($)	150,000	900,000
Savings in disposal cost ($ / yr.)	250,000	--

Figure 8
Groundwater Characterization

Parameter	Average ppb	Predicted maximum ppb
Vinyl chloride	400	900
Methylene chloride	2,200	6,000
Trans-1,2-dichloroethylene	3,000	9,500
Chloroform	5,000	20,000
Trichloroethylene	9,000	20,000
Tetrachloroethylene	6,500	9,000
1,1,2,2-tetrachloroethane	3,100	7,500
Benzene	700	1,500
1,4-dichlorobutane	-	50,000
2-methylfuran	-	50,000
Tetrahydrothiophene	-	60,000
Total recoverable phenols	270	430
Total organic carbon (mg/l)	100	150
Total cyanide (mg/l)	17	27
Total suspended solids (mg/l)	-	50
pH (units) range	6-9	
Temperature (°F) Winter	50	
Summer	70	

Figure 9

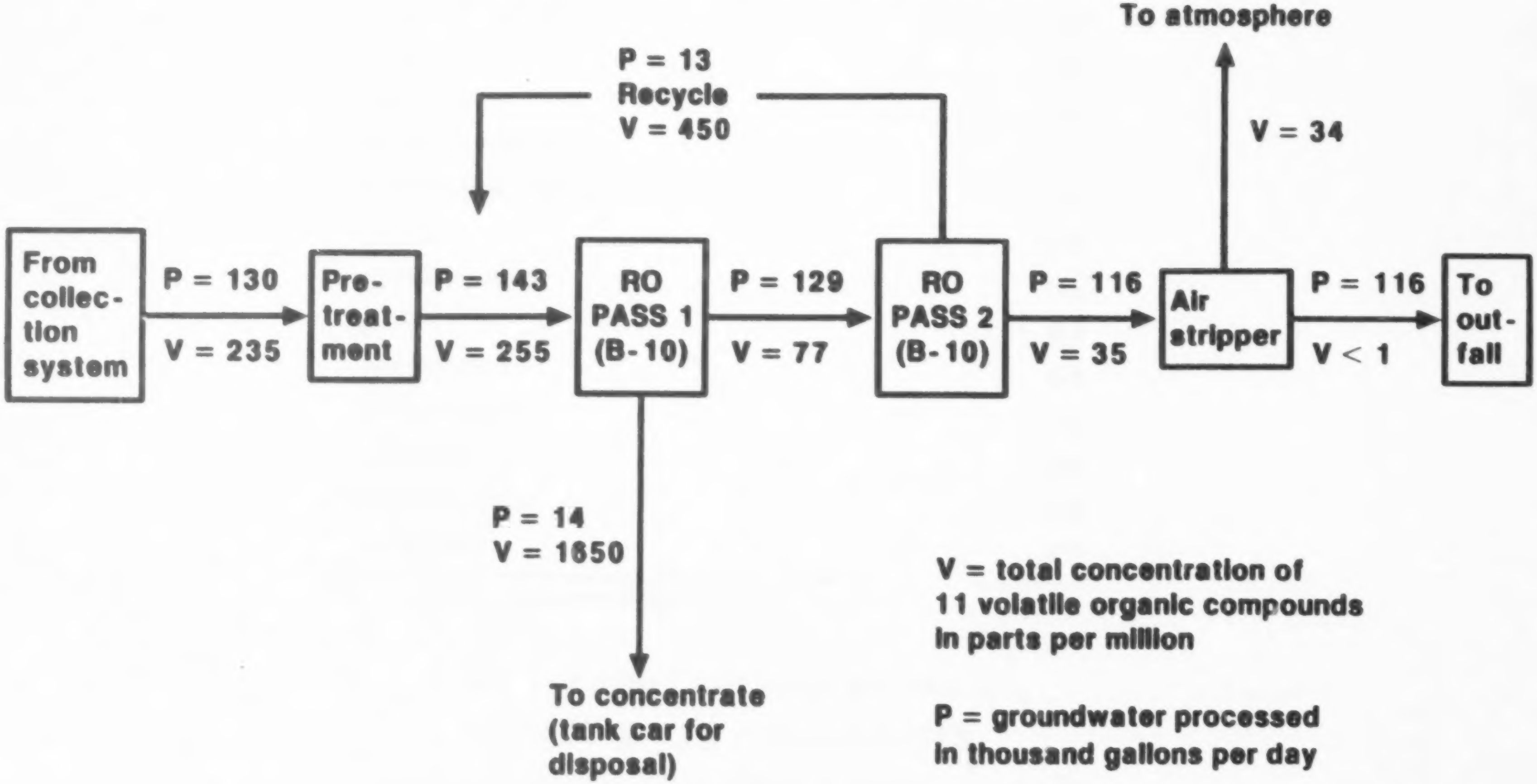
Rejection of Specific Volatile Organic Compounds Using B-10 Permeator

(At 1000 psig and 90% Recovery)

Parameter	Rejection %
Vinyl chloride	75
Methylene chloride	28
Trans-1,2-dichloroethylene	33
Chloroform	75
Trichloroethylene	49
Tetrachloroethylene	83
1,1,2,2-tetrachloroethane	95
Benzene	91
1,4-dichlorobutane	73
2-methylfuran	42
Tetrahydrothiophene	90

Figure 11

Process Description



V = total concentration of 11 volatile organic compounds in parts per million

P = groundwater processed in thousand gallons per day

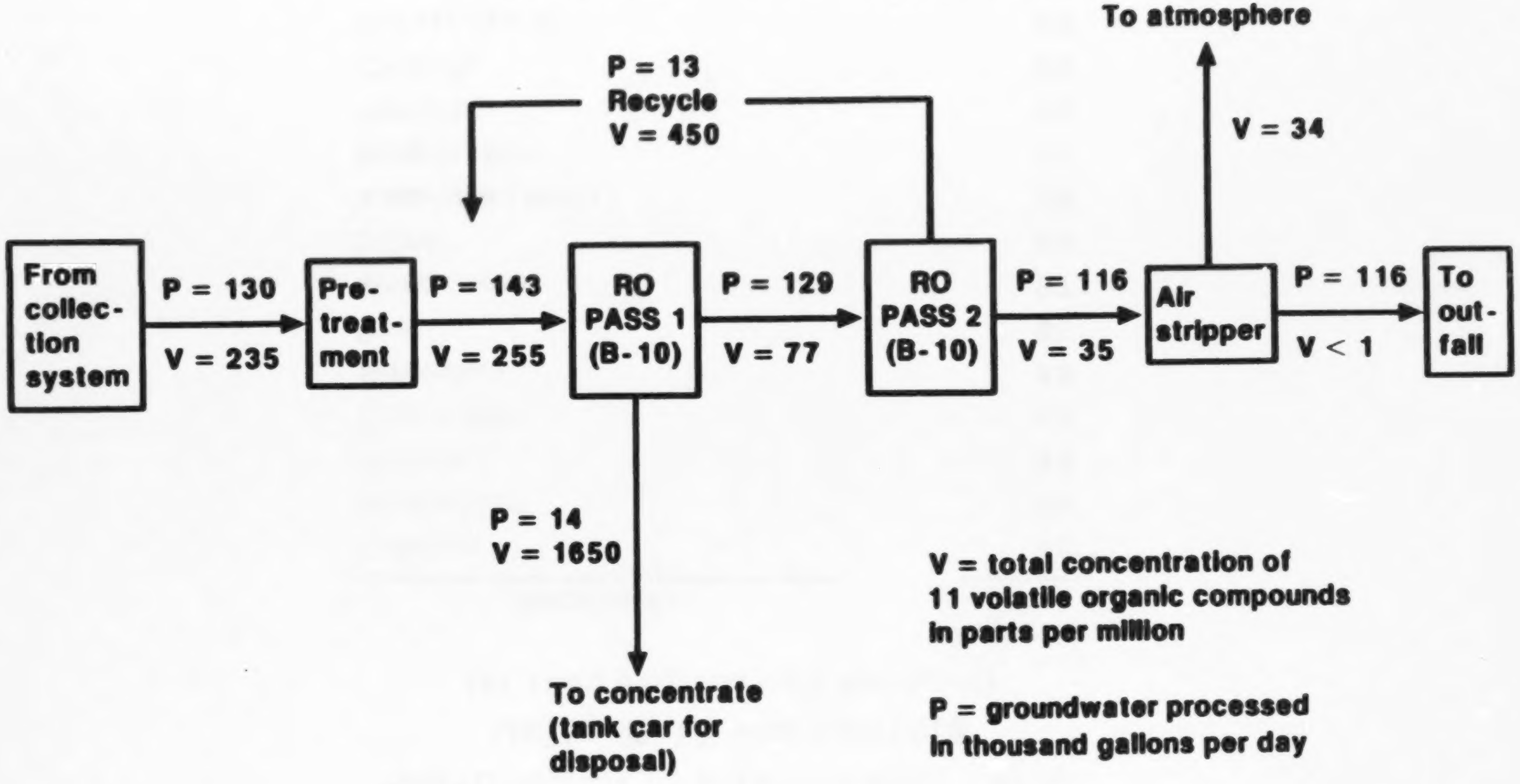
Figure 10

Rejection of Inorganics and T.O.C. Using B-10 Permeators

(At 1000 psig and 90% Recovery)

Parameter	Rejection %
Calcium	99
Magnesium	98
Sodium	93
Potassium	92
Strontium	98
Iron	69
Manganese	97
Silica	96
Ammonia (as N)	88
Bicarbonate	31
Sulfate	99
Chloride	98
Nitrate (as N)	33
Fluoride	90
Total cyanide	99
Total filterable residue (180°C)	97
Total organic carbon	75-85

Figure 11
Process Description



V = total concentration of 11 volatile organic compounds in parts per million

P = groundwater processed in thousand gallons per day

Figure 12

Projected Effluent Quality (ppb)

Constituent	Max feed	Hybrid System % rejection at 90% conversion	RO pass 2	Air stripper	Steam stripper
1,1,2,2-tetrachloroethane	7,500	95	19	4	50
Benzene	1,500	91	12	1	1
Tetrahydrothiophene	60,000	90	600	228	350
Tetrachloroethylene	9,000	83	260	1	1
Vinyl chloride	900	75	56	1	1
Chloroform	20,000	75	1,250	1	1
1,4-dichlorobutane	50,000	73	3,645	<50	1
Trichloroethylene	20,000	49	5,200	1	1
2-methylfuran	50,000	42	16,820	1	1
Trans-1,2 dichloroethylene	9,500	33	4,265	1	1
Methyl chloride	6,000	28	3,110	1	1
Total organic carbon (TOC)-mg/l	60	80	2.4	2.4	60
Phenols - μg/l	430	50	113	113	400
Cyanide - mg/l	27	99	0.003	0.003	27
TDS/heavy metals - mg/l	2,000	98	1	1	2,000

Figure 13

Economic Viability

	Hybrid membrane concentrator	Steam stripper
Capital cost $	2-2.5MM	2.5MM
Operating cost $ / yr.	600,000	500,000

Figure 14
Copper Cyanide Plating RO Recovery System

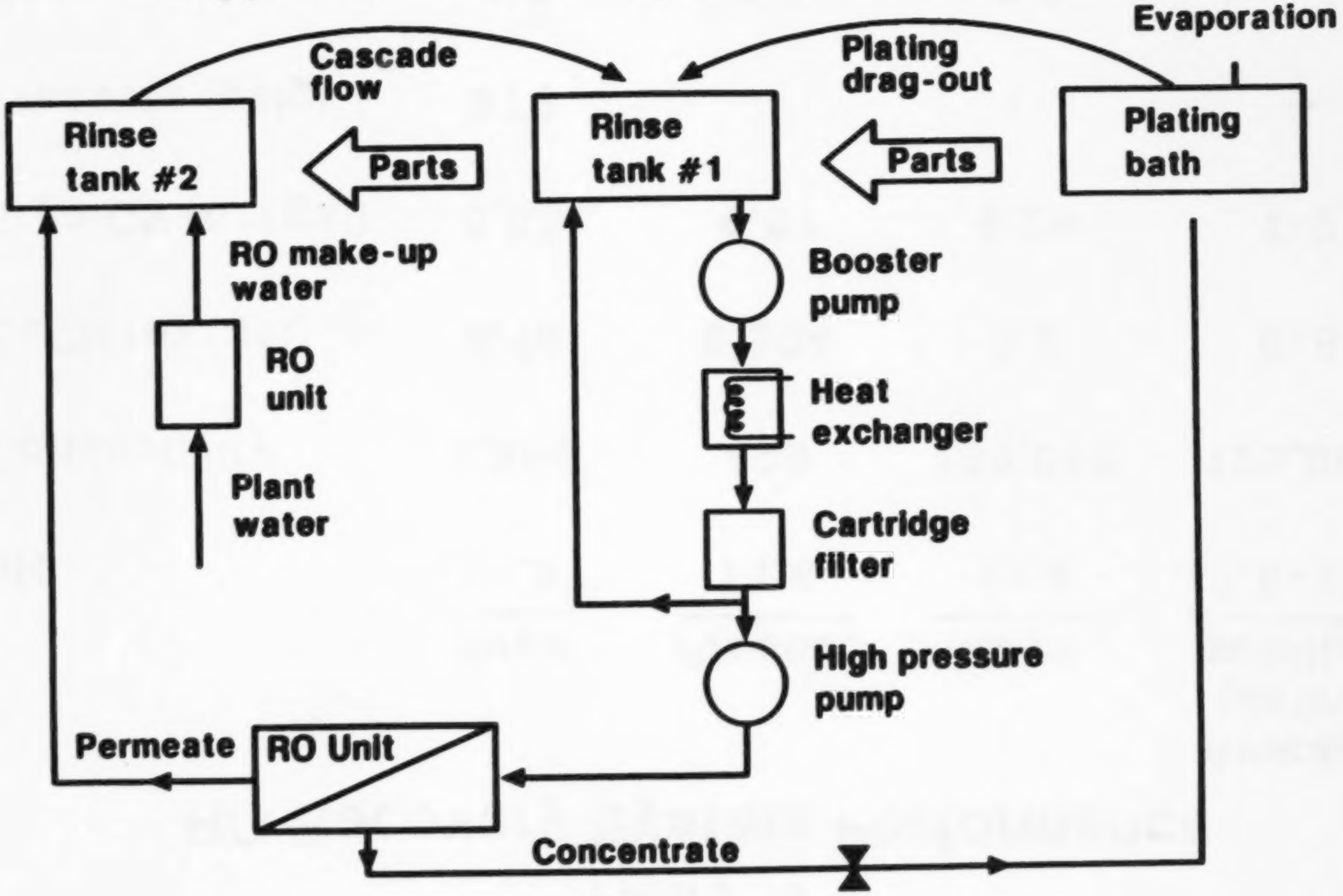


Figure 15

RO Recovery System Performance

	Feed	Product	Brine	Average plating solution
pH	11.5	11.0	12.8	12.5 - 13.9
Conductivity	4,800	400	130,000	125,000
CuCN (oz / gal)	0.18	0.004	5.8	6 - 8
Free CN (oz / gal)	0.03	0.01	0.26	1 - 2
Pressure (psig)	970	--	--	--
Flow (gpm)	2.2	2.0	0.2	--

Waste Classification and Tracking -
A Tool for Waste Minimization

Presented by
Richard A. Dennis
Manager, Environmental Affairs
Chemical Group
American Cyanamid Company
Wayne, New Jersey

ELEMENTS OF A WASTE MINIMIZATION PROGRAM

IDENTIFICATION OF WASTES

- GENERATING OPERATION OR PROCESS
- INDIVIDUAL WASTE STREAMS

WASTE CHARACTERIZATION AND CLASSIFICATION

WASTE GENERATION DATA

- QUANTITY
- COMPOSITION

WASTE DISPOSAL DATA

- METHOD
- LOCATION
- QUANTITY

DATA COLLECTION AND ANALYSIS

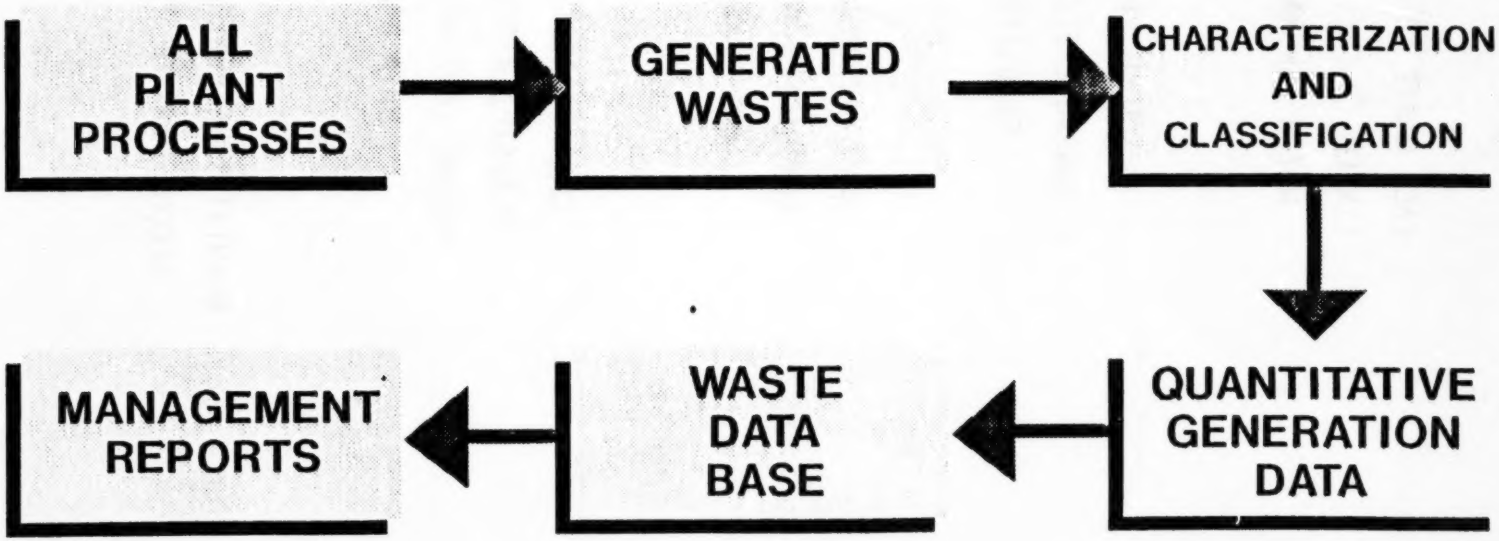
TARGETS FOR MINIMIZATION

MINIMIZATION PLANS AND SCHEDULES

IMPLEMENTATION OF PLANS

EVALUATION OF ACHIEVEMENT

WASTE TRACKING



WASTE TRACKING

EACH WASTE IS UNIQUELY
LINKED TO THE PROCESS
WHICH GENERATED IT

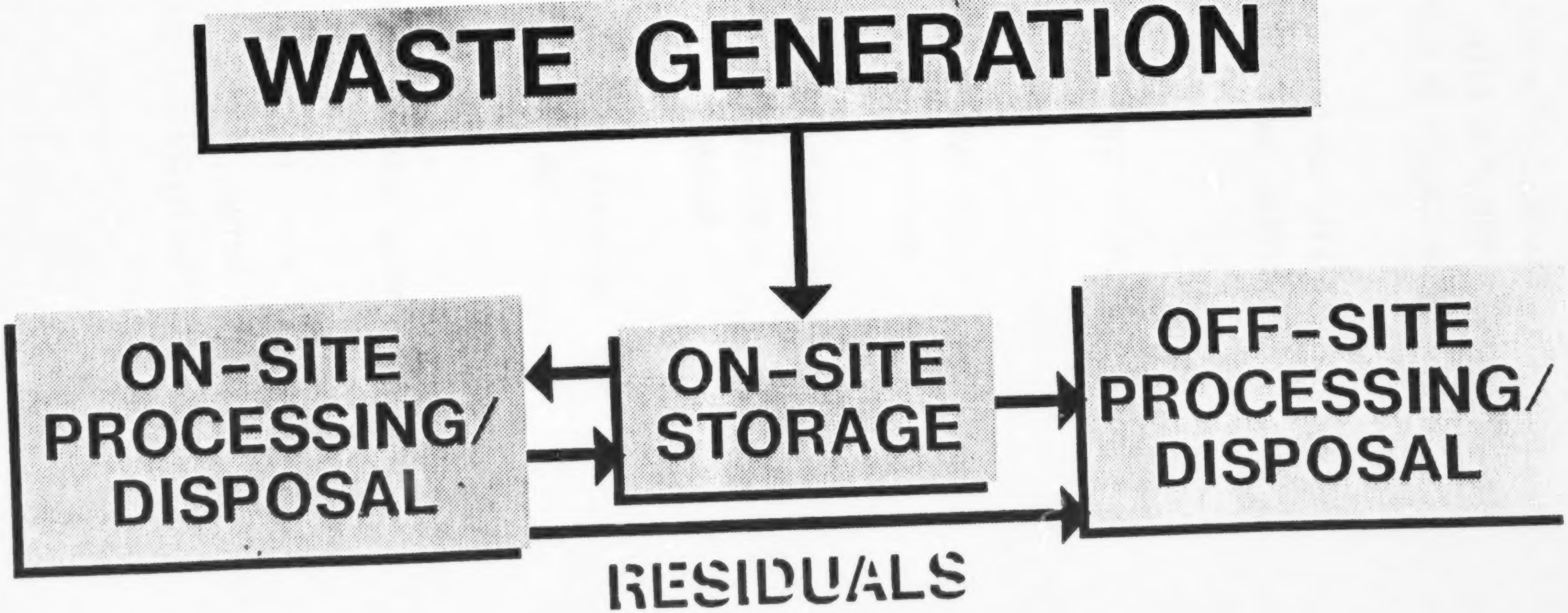
EACH WASTE IS
CHARACTERIZED AND
CLASSIFIED

CHARACTERIZATION AND
CLASSIFICATION DATA
ARE REVIEWED

CHARACTERIZATION AND
CLASSIFICATION DETAILS
BECOME PART OF THE WASTE
DATA BASE

QUANTITATIVE GENERATION DETAILS
BECOME PART OF THE DATA BASE

WASTE FLOW



WASTE GENERATION

ON-SITE STORAGE

ON-SITE PROCESSING/ DISPOSAL

OFF-SITE PROCESSING/ DISPOSAL

RESIDUALS

MANAGEMENT REPORTS SUMMARIZE DATA IN A VARIETY OF WAYS

- Generation Data By Process
- Disposal Data and Costs By Process

REPORTS SERVE TO:

1. SELECT TARGETS FOR MINIMIZATION
2. CONFIRM/EVALUATE MINIMIZATION PROGRAMS
3. ALLOCATE COSTS TO GENERATING PROCESSES
4. TRACK DISPOSAL/TREATMENT BY:
    - A. Facility
    - B. Method
    - C. Waste/Classification/Component

Hazardous Waste Reduction Auditing

Presented by
Mark Lewis, P.E.

Coauthored by:
A. J. Sederis
Hoffman-La Roche Inc.
Nutley, New Jersey

HAZARDOUS WASTE REDUCTION AUDITING

M. Lewis and A. J. Sederis
Hoffmann-La Roche Inc.

I. Principles of Waste Minimization Auditing:

A. Key elements in waste minimization program

1. Establish goals and objectives
2. Select an audit team
3. Conduct pre-audit activities
4. Perform the audit
5. Conduct post-audit activities

B. Establishing goals and objectives

1. Identify waste minimization options
2. Employee awareness/training
3. Management accountability
4. Operating practice review
5. Records review
6. Material balance
7. Flow-tracking and reporting

C. Selection of the audit team members

1. Familiar with the facility
2. Knowledgeable of environmental regulations
3. Understand work minimization techniques
4. Majority from outside department to be audited
5. Should be responsibility of corporate environmental staff

D. Pre-audit activities

1. Compilation of environmental inventory by operations staff -- discharges to air, water, and solid/liquid waste for disposal

2. Hold audit team meetings to develop work plans

3. Notify plant manager and appropriate personnel

4. Review site records

5. Prepare audit questionnaires, check lists, supporting materials covering -

    (a) facility organization

    (b) site operations and proposed changes

    (c) pollution prevention activities and programs

    (d) permits and regulated activities

    (e) areas that may be out of compliance and/or may require special attention

E. Performing the audit

1. Identify waste streams

    (a) direct (process wastes)

    (b) fugitive (evaporative)

    (c) secondary (spent cleaning solvents)

2. Evaluate waste streams

    (a) waste stream type

    (b) waste characterization

    (c) quantity

    (d) flow (continuous vs. intermittent)

    (e) media affected (air, water, and/or land)

3. Evaluate operations generating individual waste streams

4. Identify areas with greatest potential for waste minimization through -

    (a) Source reduction

        i use and alteration of input materials (purification or substitution of materials)

        ii use and modification of equipment/technology (layout, operational settings, process changes, automation, materials conservation, water conservation, energy conservation)

        iii operating practices (personnel practices, procedures, loss prevention, material handling and storage, waste stream segregation)

        iv product alteration (composition, substitution, and conservation)

    (b) Recycling options

        i reuse

        ii reclamation

        iii separation

        iv recovery

    (c) Treatment

        i type - chemical, biological, thermal

        ii efficiency

        iii applicability

        iv operating requirements - materials, energy, personnel

F. Post-audit activities

1. Report of findings

2. Management response to findings

3. Identify specific examples with best potential for waste minimization

4. Conduct feasibility study of most promising options

5. Implement most practical (and profitable options)

6. Monitor to assure objectives are met

II. An example of a waste reduction audit for a facility manufacturing medicinal products:

A. Pharmaceutical Industry

   1. Serums/vaccines, Biologicals, Extracts, Fermentation Products

   2. Pharmaceutical preparations

   3. Medicinal products

B. Modern Environmental Regulations

   1. Federal Water Pollution Control Act - 1972

   2. Federal Clean Air Act - 1970

   3. Resource Conservation and Recovery Act - 1976

C. HLR Waste Management Program - Began 1974

   1. Assess manufacturing processes to quantify pollution

      (a) Roche for twenty-five years had been estimating environmental impacts of processes - estimate fate of rm's and products to air, wastewater, solid/liquid waste

      (b) Processes ranked on basis of waste generated -

         i air emissions

         ii discharges to process sewers

         iii solid/liquid waste disposal

   2. Solid/liquid waste disposal

      (a) Identify individual waste streams

      (b) Characterize

         i physical state - solid, liquid, multiphase

         ii chemical composition

D. Waste Minimization

1. Not new concept

   (a) Chemical process development

      i optimize conditions - time-temperature, catalysts, solvents, etc. - efficient use of raw material

   (b) Recovery of solvents for reuse

      i integral part of process

2. Review waste streams for volume reduction

   (a) Different raw materials; different solvent

      i Pharmaceutical industry unique - NDA locks in process - no change in process without approval by FDA

   (b) Optimize current process - study time temperature, relationships, use of catalysts

   (c) Operator training

   (d) Automation

E. Alternatives to Off-Site Disposal

1. Recover/re-use - on site

   (a) Same process

   (b) Different process - recovered pharmaceutical raw material use in shampoo

   (c) Different use - alcohol for windshield washer fluid/gasoline additive

2. Noncommercial fuel - beneficial recovery of heat

   (a) On site burning - boiler

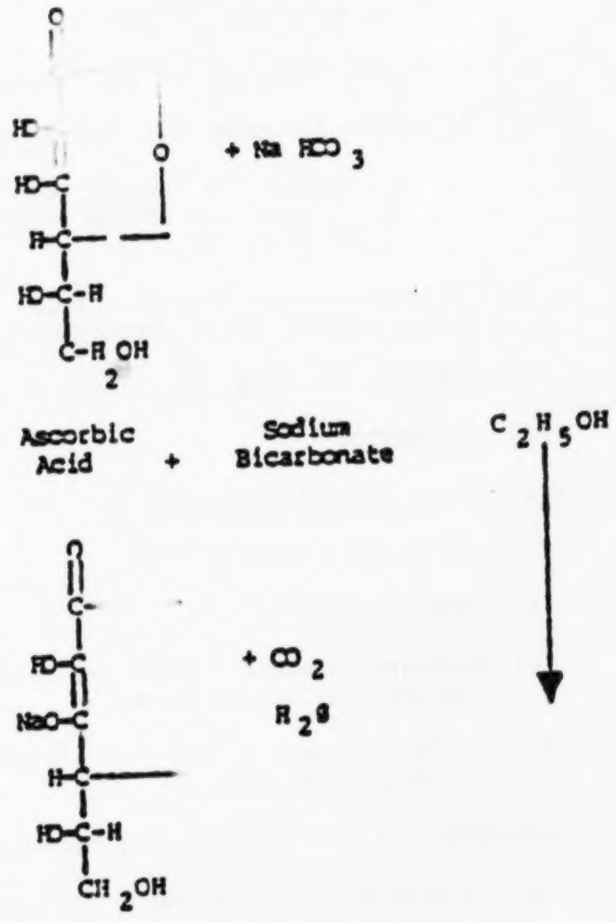
   (b) Off site industrial furnace - cement/steel

F. Example of Typical Chemical Reaction

(See Figures 1 and 2)

FIGURE 1

Sodium Ascorbate



Sodium Ascorbate + Carbon Dioxide + Water

FIGURE 2

ENVIRONMENTAL INFLUENCE ANALYSIS BY PROCESS STEP, MATERIALS

PROCESS: ASCORBIC ACID

PRODUCT CODE	PRODUCT DESCRIPTION	U/M	PRODUCTION (YTD)	PROD-DAYS (YTD)	AVERAGE WEIGHT/PROD DAY	AVERAGE WEIGHT/BATCH
60477	Sodium Ascorbate USP	KG				

***** C O N S U M P T I O N *****					***** E N V I R O N M E N T *****				
MATERIALS CONSUMED	KG/KG	ADJUSTED FOR CALC.	REQUIRED TO FORM PRODUCT	LIQUID DISPOSAL	SOLID DISPOSAL	AIR DISCIG.	SEWER DISCIG.	RECOVERY	COMMENTS
Ascorbic Acid USP	.934	.934	.889		.001	.003	.041		
Alcohol Formula 23A	.110	.110				.089	.021		
Sod Bicarbonate Bulk	.432*	.121**	.111**		.001	.004	.005		
Total	1.476	1.165	1.000		.002	.096	.067		
% of Total	100.0		85.8		.2	8.2	5.8		

Average Batch Production Kg

* As Sodium Bicarbonate
** As Sodium

WASTE REDUCTION IN PRINTING INK MANUFACTURING AND PRINTING

PRESENTED BY: PAUL VOLPE
TECHNICAL COORDINATOR
NAPIM
HARRISON, NY

GIVEN AT: HAZARDOUS WASTE REDUCTION AUDIT WORKSHOP
NOVEMBER 17, 1987

Waste Reduction in Printing Ink Manufacturing and Printing

To those of you who are in the printing ink manufacturing sector my opening remarks will be very basic, covering information which you already know very well. However, in order to put the question of waste generated by the printing ink manufacturing and printing industries into the proper perspective, let's look at what are the constituents of any printing ink regardless of the method of printing. They are:

- Colorants which impart the color you see.
- Vehicles which carry and fix the colorants to the printed substrate.
- Additives which give the ink the special physical and other properties desired.

Printing inks generally can be divided into two major groups: Paste inks used for letterpress and offset printing and liquid inks used for flexographic and gravure printing. Screen printing inks might fall into either group. Paste inks are usually oleoresinous - that is, the vehicle is composed of some type of oil and resin. Liquid inks can be either solvent based or water based and the resin systems for each are quite different.

Solvent based liquid inks almost always contain organic solvents which have flashpoints below 140°F. Some of the common solvents with flashpoints below 140° are shown here. Since the flashpoint of a printing ink is a function of the solvents used in its formulation we can conclude that most solvent based inks would have flashpoints below 140°. If a sufficient quantity of these inks enter the waste stream from your plant to cause a representative sample of the waste to have a flashpoint below 140° the entire waste would be considered hazardous from the standpoint of its ignitability.

Now what about water based inks which may contain organic solvents such as alcohols and have flashpoints below 140°? In the RCRA regulations, EPA excluded from the ignitable classification aqueous solutions with flashpoints below 140°F which contain less than 24% alcohol by volume. Although this exclusion applies mainly to solutions, EPA mentions in the preamble to the regulations liquid waste such as latex paints. Like printing ink latex paints are not true solutions but EPA includes them in the exclusion. Since they do not sustain combustion because of the high percentage of water in their formulation, EPA has stated that such wastes would not be considered ignitable even though they may have flashpoints below 140°.

Let us now consider another characteristic which may make a waste hazardous; that of corrosivity. If a waste is aqueous and has a pH of 2 or less or 12.5 or more, or is a liquid that corrodes steel at the rate of 6.35 mm (0.25 inch) per year at a test temperature of 130°F it is considered to be corrosive. I do not know of any ink or raw material generally used in inks which exhibits properties which would cause the ink to fit into the corrosive category.

The third characteristic which makes a waste hazardous is that of reactivity. We know that some inks, those which dry by radiation curing or those which are thermally activated catalyzed systems, dry by internal chemical reactions. In judging whether these inks would be hazardous because of reactivity we refer to the wording of the regulations. One of the properties given for a waste to be considered reactive is that it is normally unstable and undergoes violent change. The key words here are "unstable" and "violent". These inks as well as all other types of inks are not unstable nor do they dry by a violent chemical reaction.

On the other hand, another property of a reactive waste is that the material is capable of an explosive reaction if heated under confinement. Most organic solvents and solvent based inks stored in closed containers when heated tend to build up vapor pressures and at high temperatures may rupture the containers with an explosive reaction. However, we can conclude that no printing inks when stored at ambient temperatures and pressures would be hazardous by virtue of reactivity.

The last characteristic used to judge whether a waste is hazardous is that of toxicity based upon an extraction procedure set forth by EPA in the regulations in Appendix II of Part 261. This is called EP Toxicity. Late last year, EPA also issued in Appendix I of Part 268, covering land disposal of waste, a procedure called Toxicity Characteristic Leaching Procedure (TCLP). This is designed to determine the mobility of both organic and inorganic contaminants in the waste. It is expected that the more restrictive TCLP toxicity testing will replace EP Toxicity in determining the hazard of a waste.

The toxicity characteristic of a waste mixture such as printing ink waste is the most critical and usually the most difficult to judge when determining whether or not the waste is hazardous under the RCRA regulations. In Section 261.24 a waste is considered to be EP Toxic if, when tested by the procedure set forth in the regulations, the extract contains a concentration equal to or greater than the values given in Table 1 of this section for any of the listed contaminants. Eight metals and six organic pesticides are listed together with the maximum concentration permitted for each in the extract from a representative sample of the waste. Listed on this chart are the eight metals, but the six organics have been omitted since it is not reasonable to expect any ink waste to contain these materials.

Whether or not the listed metals are present in an ink depends principally on the pigments used. Of these metals, the ones which are potentially the most likely to be introduced by ink are lead, chromium and barium. The other metals, arsenic, mercury, cadmium, selenium and silver are only expected to be present in ink as trace contaminants, if present at all.

Note that earlier I said concentration in the extract and not in the waste itself. It must be understood that the level of "toxic" materials such as barium, lead or chromium in the ink does not in itself determine whether the waste is EP Toxic. The determining factor is the quantity of the toxic metal which is leached from a representative sample of the waste.

If the inks do not contain pigments which are compounds of lead and chromium (such as lead chromates and molybdate orange) it is most unlikely that sufficient lead and chromium would be present to result in the leaching of these metals in excess of the given limits. On the other hand, many clean yellow shade reds are formulated with pigments which are compounds of barium and sufficient barium could be present resulting in the leachate containing barium in excess of the limit.

Several years ago, the National Printing Ink Research Institute at Lehigh University ran a series of EP Toxicity tests on a wide range of ink-related wastes in an attempt to determine which would or would not be EP Toxic. It was hoped that the results would indicate on a broad scale the types of ink related wastes which could be considered non-toxic without having to test samples of each individual waste stream. Unfortunately, when the wastes contained lead or barium based pigments, the test results showed that no definite conclusions could be drawn. While the majority of the samples were found to be EP Toxic, some were not. Included in the samples were water flexo inks, some containing lead chromate and others, barium-based pigments. Also tested were samples of the actual pigments. Shown on this chart are the results obtained from these samples.

The only conclusion that can be made is that the test for EP Toxicity is very waste specific. Because of this, ink manufacturers cannot give any assurances to their customers that the inks they supply would not be EP Toxic if the inks are formulated with pigments which are barium or lead/chromium based. The best solution is to avoid mixing waste from inks containing these metals with other non-hazardous waste. In fact, the solution to the entire problem of waste disposal is to reduce the amount of waste generated. How does one go about doing this?

To begin with, use common sense. This morning we heard several speakers give talks on waste auditing. Find out where your waste is being generated, what type of waste and how much. Keep in mind that a material does not become a waste until you judge it to be unusable. This can be a major factor in reducing the amount of waste generated.

Let's look at solvents used for cleaning equipment. Many have flashpoints below 140° and thus would be considered hazardous if they entered the waste stream. Many times clean up solvents are used once and then thrown into the waste or slop bucket together with other waste, some of which is even non-hazardous, making the whole mess hazardous. Why not save the wash-up solvent and use it over and over again. You will find that even though the solvent is somewhat dirty it still does a good job in removing ink from the equipment and presses. A little virgin solvent may be necessary for final clean-up but this usually just requires a rag moistened with the clean solvent.

By placing your wash-up solvent in a drum after it is used to clean equipment, you will find that the solids normally tend to settle out and the solvent toward the top of the drum can then be used many times before it gets too dirty to be effective. An ink manufacturer making solvent-based inks can also recycle his wash-up solvent after it is used several times into the next batch of black ink which he makes. A flexographic printer using solvent-based inks normally reduces his inks at press-side with solvent. He can also recycle his wash-up solvent when he reduces either blacks or dark colored inks on press. Keep in mind, however, that recycling the wash-up solvent will only work if you keep the solvent separated from other wastes.

What about waste water from washing equipment or presses where water-based inks were used? Here again, the solution is to use a minimal amount of water for clean-up. Don't use what I call the "garden hose" method. In the past it was common practice for printers to wash water-based inks from presses by placing a garden hose into the ink fountain and flushing everything down into the sump. They ended up with a massive amount of colored water which usually went into the sewer. Today this will not work since most municipal sewer departments will no longer accept this material. How then can you effectively dispose of or reuse this wash water?

If you separate the solids either by filtration or precipitation, you effectively remove the colored pigments and then the clear water can be reused for clean-up, for making press-side reductions, or added to the glue used in most corrugated operations and what cannot be reused could then be placed down into the sewer.

What about waste ink? In my opinion, no ink should be wasted and very little should enter into the waste stream. As an ink manufacturer you paid for every raw material used in making your inks. As a printer, you paid for every pound of ink which was shipped to your plant. So why waste this material? Most ink manufacturers use so-called off-standard inks as work-off in subsequent batches. If all else fails the work-off can be used in batches of black inks. Printers can do the same with the small quantities of ink remaining from press runs. Press returns should be carefully stored by individual color and used during subsequent runs. For example you can mix all left over yellows together; do the same with the other colors. When you have a sufficient quantity you could then use the resulting ink for other print jobs.

Another example - let's say you have some yellow left over and blue left over. If you mix the two you end up with a green ink that you possibly could use for another print job. The same applies to let's say yellow and red - you could make an orange. If this is not possible you could still add these leftover ink colors to whatever black inks you are running.

In certain states, such as New Jersey, where even oil based inks are considered hazardous due to the fact that oily waste is deemed to be hazardous, reducing the amount of waste ink can save you money. Not only because you do not throw out materials you have already paid for, but you save the cost of having it hauled away as a hazardous waste.

Now a word about empty containers which previously held inks or raw materials. These are not considered hazardous under the Federal RCRA regulations even though they might still contain a small amount of residue of a material which might otherwise be considered hazardous. EPA has defined an empty container as one from which all material has been removed that can be removed using practices commonly employed to remove materials from that type of container. The definition further states that no more than one inch of residue remain on the bottom on the container. After scraping as much of the contents from your metal containers you could then crush them and after accumulating a sufficient quantity dispose of them by selling to a scrap metal dealer. If you are not able to do this, you could still dispose of them with your ordinary trash at a much lower cost versus hauling away as a hazardous waste.

I would like to conclude by saying - take a hard look at your waste. I'm sure that by doing this you can come up with many more ways to reuse materials that in the past entered the waste stream from your plant. This will not only minimalize your waste disposal problems, but also save you money.

Slide 1

PRINTING INK CONSTITUENTS

COLORANTS - PIGMENTS
DYES

VEHICLES - RESINS
SOLVENTS

ADDITIVES - WAXES
ANTIFOAM AGENTS
SLIP AGENTS

Slide 2

COMMON FLEXO INK SOLVENTS

Flash Point Below 140°F (Closed Cup)

IGNITABLE

TYPE	EXAMPLES
ALCOHOLS	Methyl Alcohol
	Ethyl Alcohol
	Isopropyl Alcohol
	Normal Propyl Alcohol
ESTERS	Ethyl Acetate
	Isopropyl Acetate
	Normal Propyl Acetate
GLYCOL ETHERS	Cellosolve
	Methyl Cellosolve
ALIPHATIC HYDROCARBONS	Hexane
	Heptane
	VM&P Naphtha
AROMATIC HYDROCARBONS	Toluene
	Xylene
KETONES	Methyl Ethyl Ketone
	Methyl Isobutyl Ketone

Slide3

EP TOXIC-SECTION 261.24

A waste is EP Toxic if leachate from extraction test contains more than:

	5.0 Mg/L
ARSENIC	100.0
BARIUM	1.0
CADMIUM	5.0
CHROMIUM	5.0
LEAD	0.2
MERCURY	1.0
SELENIUM	5.0
SILVER	

Plus six organics not found in printing inks.

B34/10

PRINTING INK

SOLID WASTE SURVEY

Sample Type	Number Tested	Number Over EPA Limit			
		total	Pb	Pb/Cr	Ba
Water Flexo Inks containing Lead/Chromium:	15	8	7	1	●
Lead/Chromium Pigments*:	18	15	13	2	●
Water Flexo Inks containing Barium Pigments:	11	3	●	●	3
Barium Pigments**:	7	3	●	●	3

* Pigment samples included:
Medium Chrome Yellow, Primrose, Light Chrome Yellow and Molybdate Orange.

** Pigment samples included:
Barium Lithol (R49:1) and Red Lake C (R53:1).